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INVESTIGATIONS OF FUSARIUM WILT OF MUSKMELONS AND WATERMELONS IN SOUTHWESTERN ONTARIO[1]

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INTRODUCTION

Melon production in southwestern Ontario has increased considerably during the last 20 years in response to the demand for fresh vegetables. Good prices and high average yields, with consequent high cash returns per acre, have resulted in the extensive planting of this crop along with other early vegetables on many farms previously planted with flue-cured tobacco. Largely because of early harvesting, the extreme southern part of Essex County, generally known as the Harrow-Leamington district, has become an important melon-growing area. Although both watermelons and muskmelons are grown throughout this area, during the last few years the latter have comprised more than 90 per cent of the acreage planted to these two crops.

Coincident with the expanding acreage of melons have appeared a number of important diseases that affect these crops (1). Fusarium wilt, caused by *Fusarium oxysporum f. niveum* (EFS) Sny. & Hans., has proved to be one of the most destructive.

The continual increase in prevalence of wilt in muskmelons has not only seriously limited production in Essex County, but has forced many growers to discontinue the growing of this crop. More recently, Fusarium wilt in watermelons has also been present in Essex county. The disease appeared in 3 fields, 2 of which were known to be heavily-infested with the muskmelon wilt pathogen. These observations led to a study of the fungi causing wilt in both muskmelons and watermelons. The results of pathogenicity tests on both hosts, together with certain observations concerning disease severity and spread, are presented in this paper.

REVIEW OF LITERATURE

The presence of Fusarium wilt of watermelons has been recognized for upwards of 60 years in different parts of United States and, in the main, the disease has been found wherever the crop has been grown (8, 12). In 1930 and 1931, Fusarium wilt of muskmelons suddenly became destructive in Minnesota and New York. Leach and Currence (4) showed that the fungi causing wilt in watermelons and in muskmelons were closely related, though they differed strikingly in pathogenicity. They found that the fungus causing watermelon wilt would not attack muskmelons and, con-

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versely, the fungus causing muskmelon wilt would not attack watermelons. Accordingly, the respective fungi were designated as Forms 1 and 2 of *Fusarium bulbigenum* var. *niveum*. In a study of the muskmelon wilt occurring at Burlington, Ontario, Miller (6) found that the fungus did not attack other cucurbits. In 1948, Hendrix, Du Charme and Murakishi (3), working in Minnesota, showed that some isolates from wilted watermelons attacked muskmelon seedlings and that certain isolates from muskmelon attacked watermelons. Moreover, they found that, on the original hosts, different isolates caused from 0 to 100 per cent mortality and that several isolates from watermelon caused a more severe reduction in stands of muskmelon than of watermelon seedlings.

OCCURRENCE AND DISTRIBUTION OF WILT IN SOUTHERN ONTARIO

The occurrence of Fusarium wilt of muskmelons in Ontario was first reported in 1936. In that year, the disease was observed to cause considerable losses on a farm in the Niagara Peninsula, and the grower reported that the trouble had been present 2 or 3 years previously. Subsequently, the disease has been reported present in several widely separated localities in the province, but not until 1943 was it found in the principal melon-growing area of Essex County. In 1944, it caused losses estimated at 10 per cent on 3 farms in the Harrow area. By 1947, all fields on these 3 farms had become so heavily infested that the growers were forced to discontinue the growing of muskmelons. At the same time, wilt appeared on several other widely separated farms in the Leamington area. Surveys conducted by the writer in 1950 revealed that only a small percentage of the farms in the Harrow-Leamington district were free from wilt and that several farms were so heavily infested that it was no longer possible to grow profitably a wilt-susceptible variety. Thus, within a decade, the muskmelon wilt organism has invaded and to a large extent "overrun" much of the chief melon-growing district in south Essex.

Although watermelons have been grown less extensively and less continuously in part of the same area for more than 50 years, Fusarium wilt was not observed to attack this host until 1948. In that season, the pathogen was isolated from wilted watermelons taken from 3 farms in the Harrow area. Subsequently, on one farm, where the progress of wilt has been carefully followed, the disease has increased rapidly and spread far beyond the initially infested areas.

LOSSES IN MUSKMELON GROWN ON INFESTED SOIL

Because of the limited distribution of Fusarium wilt in south Essex prior to 1947, losses from the disease were not large. Since then, losses have been extensive because many growers have been unable to avoid planting on infested soil owing to the limited acreage suitable for growing early melons. Consequently, due to the short crop rotation ordinarily employed in this area on early vegetable soils, it has been possible to observe carefully the progress of wilt on many farms. Results of disease surveys to determine the incidence of muskmelon wilt in recently infested areas are presented in Table I.

TABLE 1.—RELATION OF THE SUCCESSIVE CROPPING OF MUSKMELONS TO THE INCIDENCE OF FUSARIUM WILT IN THAT CROP

Farm	Wilt record of field	Percentage wilted or dead plants		
		2 weeks prior to harvest	First picking	Mid-harvest
1a	3% in previous crop	26.6	69.4	
1b	2% or less in previous crop		44.1	
2	Trace; adjoining field heavily infested	33.9	75.5	
3	2% or less in previous crop	18.0	44.5	
4	10% in previous crop	86.5	98.2	
5	4% in previous crop			75.0
6	5% or less in previous crop			41.0
7	Trace in previous crop			25.0
8	Trace; adjoining field moderately infested			47.0
9	5% in previous crop			89.3

As Table 1 shows, the muskmelon wilt pathogen has proved capable of multiplying rapidly soon after its initial appearance in a field, and, even in the second year of its occurrence, has been observed to cause losses up to or exceeding 60 per cent. That the increase of wilt on many farms could not be attributed to seed transmission was evident because seed obtained from the same grower, when planted in other fields, produced a crop free from wilt.

A typical field of muskmelons attacked by Fusarium wilt, with one centre of infestation, is shown in Figure 1.

EXPERIMENTAL

Part of the object of this investigation was to determine whether or not strains of the muskmelon wilt organism were present in southwestern Ontario. The sudden appearance of wilt in watermelons in localized areas of 3 fields known to be heavily infested with the muskmelon pathogen suggested the existence of strains of the wilt fungus capable of attacking both hosts. The following experiments were carried out to investigate this possibility.

Isolation and Maintenance of Cultures

Miller (7) has shown that pure cultures of the muskmelon wilt Fusarium, when not transferred, remained viable in soil tubes for at least 5 years, and meanwhile showed no change in cultural characteristics or loss of pathogenicity. In contrast, after a few weeks, the wild type was to a large extent displaced by mutants on slants of P.D.A. Similar tests with

this fungus were conducted by the writer over a period of 4 years and have confirmed Miller's findings. Thus, the soil tube culture method was demonstrated to be most useful in maintaining the wild type and consequently this method was employed in this study.

The procedure for isolation and handling of cultures as used in this study was as follows: Small pieces of brownish vascular tissue were removed aseptically from the hypocotyl of wilted plants and placed on plates of P.D.A. Approximately 96 hours later, microconidia were washed off and transferred to other P.D.A. plates. From the latter, single, germinated microconidia were moved to another set of plates of P.D.A. for 48 hours and then mass transfers of hyphae were made to tubes of steamed, sandy loam soil. The cultures were held for a few days at room temperature and were then stored in a refrigerator at 5° C.

Isolates were obtained from wilted muskmelon and watermelon plants from several widely separated fields in the Harrow-Leamington district. Twelve isolates were obtained from muskmelon and 3 from watermelon plants. With the exception of one isolate from muskmelon that was obtained in 1947, the other isolates used in pathogenicity tests reported in this paper were procured in 1948 and maintained in soil tubes until the summers of 1949 and 1950, when tests were conducted.

Cultural Characteristics of Isolates

The 12 Fusarium isolates obtained from muskmelons were initially alike when grown on P.D.A. and corresponded with the description of the fungus given by Leach (4) and Miller (5). One of the isolates from watermelon was slightly different from the other two in that it produced a slightly deeper pigment on P.D.A.

Pathogenicity of Isolates

(a) Tests with isolates from muskmelon

A preliminary experiment conducted in the summer of 1949 indicated slight differences in virulence among certain of the 12 isolates from muskmelons. Two further experiments were conducted, one later in 1949 and the other in 1950, with 6 of the 12 isolates that appeared to differ most widely in virulence. For comparison, an isolate from muskmelon obtained from Minnesota was included in the test. For these experiments a quantity of steamed soil sufficient to fill 28 flats was divided into 7 equal portions, and each portion was inoculated with a different isolate and used to fill 4 flats. The inoculum from 8-day-old cultures grown on a sand-cornmeal medium was incorporated into the soil at the rate of 1 per cent by volume. A series of 4 flats containing non-inoculated soil constituted the check. The varieties and the number of seeds of each planted in an individual flat were as follows: (a) Muskmelon—Hoodoo 150, Iroquois 100; (b) Watermelon—Cole's Early 40. To reduce the pre-emergence mortality the seeds were treated with thiram.

During the course of these experiments greenhouse temperatures ranged from 65° – 100° F. Daily records of emergence and wilting were kept. The results from the two experiments were similar and averages are presented in Table 2.

FIGURE 1. Muskmelon field showing central area infested with Fusarium wilt.

TABLE 2.—THE REACTION OF MUSKMELON AND WATERMELON VARIETIES TO WILD TYPE ISOLATES OF THE MUSKMELON WILT FUNGUS

Isolate	Percentage wilt after				
	17 days			35 days	45 days
	Hoodoo	Iroquois	Cole's E.	Cole's E.	Cole's E.
A	90.8	96.5	0.0	4.8	4.8
B	96.4	97.2	3.2	8.9	8.9
C	88.3	97.2	4.4	7.9	7.9
D	97.0	99.0	3.9	8.9	8.9
E	89.3	95.4	2.9	9.3	9.3
F	89.2	93.3	0.7	4.8	4.8
Minn. D*	94.9	99.0	1.5	6.7	6.7
Check (no inoculum)	0.0	0.0	0.0	0.0	0.0

* This isolate was kindly submitted by H. Murakishi, at that time a post-graduate student in the Department of Plant Pathology, University of Minnesota.

TABLE 3—THE REACTION OF WATERMELON AND MUSKMELON VARIETIES TO 3 WILD TYPE ISOLATES OF THE WATERMELON WILT FUNGUS

Experiment	Isolate	Percentage wilt after					
		17 days			35 days		
		Cole's E.	Miles	Hoodoo	Cole's E.	Miles	Hoodoo
1	R	89.5	0.0	0.0	98.0	18.2	0.0
	S	88.4	20.3	3.8	99.5	52.6	3.8
	T	30.0	10.5	1.6	98.8	92.2	1.6
	Check (no inoculum)	0.0	0.0	0.0	0.0	0.0	0.0
2	R	80.5	0.0	0.0	100.0	38.8	0.0
	S	80.9	33.9	0.0	100.0	72.1	0.0
	T	59.7	30.0	0.0	100.0	100.0	0.0
	Check (no inoculum)	0.0	0.0	0.0	0.0	0.0	0.0

As Table 2 shows, all isolates were highly pathogenic to both the Hoodoo and the Iroquois variety of muskmelon and were weakly pathogenic to the Cole's Early variety of watermelon. The isolate from Minnesota showed the same parasitic capabilities as did the isolates from Ontario. Sufficient differences in virulence were not displayed by any of the isolates to indicate the existence of strains. The amount of wilt caused in the

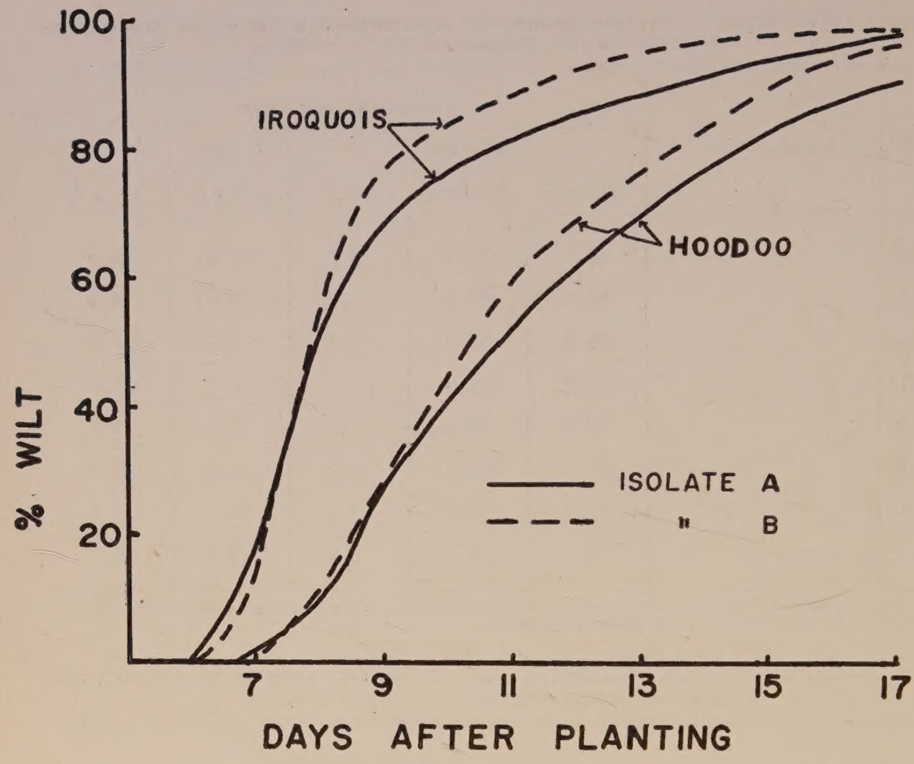

FIGURE 2. Daily progress of Fusarium wilt in Iroquois and Hoodoo muskmelon seedlings as caused by 2 wild type muskmelon isolates.

watermelon seedlings was small and, though wilting occurred up to the 35th day, the greater percentage of it developed between the 17th and 35th day. The daily progress of wilt in the two muskmelon varieties induced by 2 isolates, as represented graphically in Figure 2, indicated that the resistant variety Iroquois is attacked more readily than the completely susceptible variety Hoodoo. That the former is susceptible only in the seedling stage has, however, been repeatedly demonstrated in recent years by the fact that, when plants well past the seedling stage were transplanted into heavily-infested soils, they remained healthy.

(b) Tests with isolates from watermelon.

A preliminary experiment conducted in the greenhouse in July of 1949 showed comparatively large differences in virulence among the three isolates from watermelon. Two further experiments were conducted in 1950 in a manner similar to that described above for the tests with isolates from muskmelon. In the first experiment, 3 flats of steamed soil were inoculated with each isolate and in the second one, 4 flats were inoculated. The varieties and the number of seeds of each planted in an individual flat were as follows: (a) Watermelon—Cole's Early 75 and Miles 65, and (b) Muskmelon—Hoodoo 25. The seeds were treated with thiram. The results of these two experiments are assembled in Table 3.

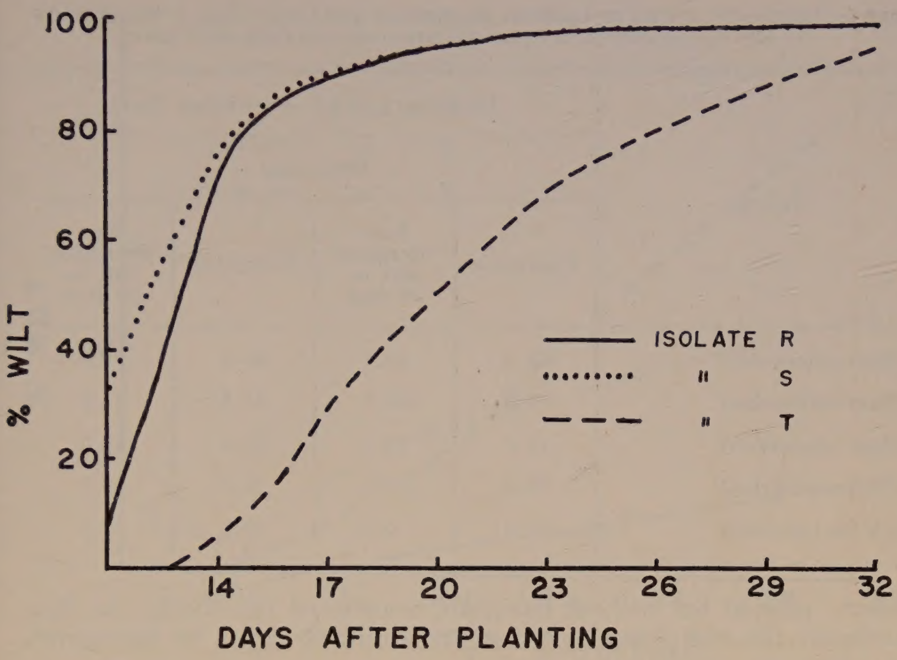

FIGURE 3. Daily progress of Fusarium wilt in Cole's Early watermelon caused by 3 wild type watermelon isolates.

The results of the two experiments presented in Table 3 are in close agreement and show that the 3 isolates derived from watermelons were much more pathogenic to their original host than to muskmelon. Figures 3 and 4 show graphically, for the first experiment, the daily progress of the wilt induced by the 3 isolates in the two watermelon varieties. It is apparent that the Cole's Early was more susceptible than the Miles variety. Isolates R and S were more virulent than isolate T on the former variety, whereas, on the latter variety, isolate T was the most virulent and isolates S aud R were, in descending order, less virulent. On this variety the 3 isolates showed such consistent and marked differences in virulence that they may be regarded as distinct strains of the watermelon wilt fungus.

(c) Test with untreated seed

Since isolates from both watermelons and muskmelons were each capable of causing a certain amount of wilt in the other host despite the protection provided by seed treatment, it seemed desirable to ascertain the extent of parasitism when seed treatment was not employed. One such test is outlined and discussed below.

A quantity of steamed soil sufficient to fill 8 flats was divided into 4 equal portions, and each portion was inoculated with a different isolate and used to fill 2 flats. The soil was inoculated with 15-day-old cultures at the rate of 1 per cent by volume. Three isolates from muskmelon and one from watermelon were used in this test. The varieties and the number of seeds of each planted in an individual flat were as follows: (a) Muskmelon—Iroquois 150, and (b) Watermelon—Cole's Early 100. Two flats,

TABLE 4—INCIDENCE OF WILT IN IROQUOIS MUSKMELON AND COLE'S EARLY WATERMELON IN SOIL INOCULATED WITH FUSARIUM WILT ISOLATES FROM BOTH HOSTS

Isolate	Iroquois		Cole's Early	
	Percentage			
	Emergence	Post-emergence wilt in 26 days	Emergence	Post-emergence wilt in 26 days
S (from watermelon)	78.6	42.7	45.0	97.0
B (from muskmelon)	69.0	100.0	43.5	87.0
E (from muskmelon)	75.0	99.5	43.5	70.0
F (from muskmelon)	78.6	100.0	51.0	87.2
Check (no inoculum)	81.0	0.0	79.0	0.0

similarly planted but without inoculum, constituted the check. In this experiment the seed was not treated with thiram. Data on emergence and wilting are summarized in Table 4.

Results presented in Table 4 show that, in so far as pre-emergence attack is concerned, all isolates caused appreciable mortality in Cole's Early watermelon but only a small amount in Iroquois muskmelon. With respect to post-emergence attack, the 3 isolates from muskmelon caused virtually 100 per cent wilt in Iroquois within 26 days. Although the isolate from watermelon caused only a 42 per cent reduction in stand of Iroquois during the same period, many of the surviving seedlings remained much stunted as a result of seedling root infection. The isolate from watermelon proved to be only slightly more pathogenic to watermelon than were the isolates from muskmelon.

Although isolates from muskmelon and watermelon were each capable of attacking seedlings of both hosts both before and after emergence, there were obvious differences in the nature of the attack. The muskmelon pathogen showed a marked capacity to attack cotyledonary tissue in watermelons before the seedlings had completely emerged from the soil. Lesions produced at the base of the cotyledons and in the adjoining hypocotyl tissue (Figure 5A), frequently girdled the stem and killed the plant. In seedlings less severely attacked, a lesion involving the growing point, the base of one cotyledon and one side of the hypocotyl was commonly observed (Figure 5A). This type of attack was particularly common in watermelon seedlings that were slow to emerge, and, though less frequently, was also found in seedlings that arose from treated seed. Although isolates from watermelon occasionally produced lesions of the above-mentioned type in that host, usually the root and the base of the hypocotyl (Figure 5B) were the loci of attack.

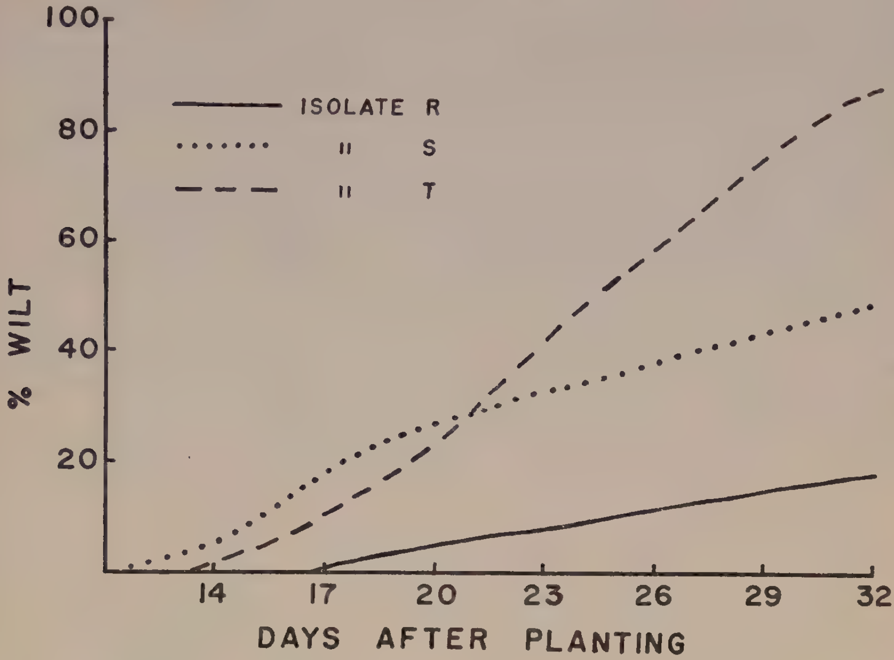

FIGURE 4. Daily progress of Fusarium wilt in Miles watermelon caused by 3 wild type watermelon isolates.

DISCUSSION

The results of the present studies show that all isolates from muskmelon were highly pathogenic to muskmelons, and, in so far as seedling reactions were concerned, none differed significantly in virulence. Thus, it would seem that the variation from farm to farm, both with respect to the extent of losses and the time of appearance of the muskmelon wilt in the field, can be explained by such variable factors as the degree of soil infestation, soil moisture differences, and nutrition of host, all of which have been shown to affect the expression of the disease (9, 11).

The finding of 3 isolates of the watermelon wilt fungus differing widely in virulence is in striking contrast with that observed in the muskmelon organism. Since, for both pathogens, the same technique was used for isolation, maintenance of cultures, and testing of pathogenicity, it might logically be assumed that the strains found in the watermelon fungus existed as wild types and were not merely cultural variants.

With respect to the high virulence of all isolates on the original host, the results presented in this paper are not in agreement with those reported by previous investigators. Sleeth (10) found that under conditions of greenhouse tests, isolates of the watermelon wilt fungus ranged from non-pathogenic to highly virulent. Similarly, Hendrix *et al.* (3) reported that, when tested on the original hosts, different isolates from muskmelon and watermelon caused from 0 to 100 per cent wilt. The explanation for these differences is probably to be found in the method of isolating and maintaining the wild type in culture. In this connection, the writer was careful to

isolate from infected vascular tissue of incipient lesions and to culture the wild type isolates so obtained on agar medium for only a limited time prior to their transfer to tubes of steamed soil on which they were afterwards maintained. Although previous investigators were familiar with the dissociation phenomena displayed by Fusarium wilt fungi when grown on agar, nevertheless, most of them maintained their cultures on nutrient-rich medium for a considerable time. Miller (5) found that the wild type of the muskmelon Fusarium, when maintained on P.D.A., was readily displaced by mutants. Furthermore, he found that cultures had frequently changed in two months or less, even when mycelial transfers were made every week or two. He also found that the mutants were usually less pathogenic than the wild type. Thus, it is possible that earlier investigators in this field were in some cases working with certain cultural variants, rather than with the original types occurring in nature.

The question arises, how can the recent appearance of watermelon wilt in southwestern Ontario be explained? The results of the pathogenicity tests presented in this paper indicate that the fungus causing wilt in watermelons is quite distinct from the one causing wilt in muskmelons and that neither can attack the other host except in the seedling stage. There would seem to be little support for the hypothesis that the watermelon fungus arose by mutation from the muskmelon fungus. If, however, that hypothesis is held, then it is necessary to assume that the mutants have lost or at no time possessed the capacity to infect muskmelons except in the seedling stage. Although several other possibilities as to the origin of the watermelon wilt fungus in Ontario cannot be ruled out, the likelihood is that it was introduced from the United States on watermelon seed. Fulton and Winston (2) showed that watermelon wilt could be spread by contaminated seed. Small amounts of watermelon seed have been brought into Canada from that country at various times and planted on farms in Ontario. A record of planting on 2 of the 3 farms where watermelon wilt occurred showed, however, that the growers concerned had not obtained seed from the United States or from seed firms for 5 or 6 years prior to the outbreak of wilt. Thus, while the probable existence of strains of this fungus in the United States, as indicated by Sleeth, lends some support to the seed-borne origin of the disease, nevertheless, considerable difficulty is met with in accounting for the interval of 5 or 6 years between the planting of introduced seed and the appearance of watermelon wilt on the farms in question.

The most satisfactory control of these two wilts is the growing of wilt-resistant varieties. Growers must be cautioned, however, with respect to the seeding of a resistant variety of muskmelon, such as Iroquois, in heavily-infested soil. Because of its extreme susceptibility in the seedling stage, losses may be encountered if it is seeded directly in the field. To avoid the possibility of serious losses in heavily infested soils, the practice of setting out young plants of this variety in the field should be followed.

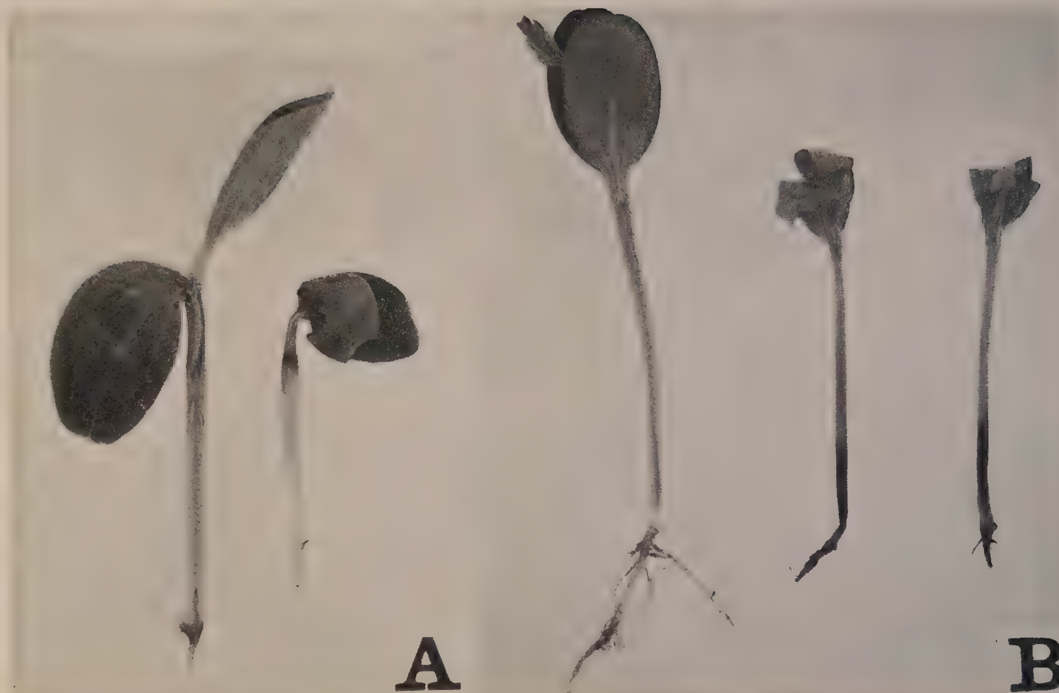

FIGURE 5A. Watermelon seedlings showing lesions originating at base of cotyledons caused by the muskmelon wilt organism. B. Two watermelon seedlings at right showing characteristic symptoms of wilt caused by the watermelon wilt organism. Healthy seedling at left.

SUMMARY

Within the last decade, Fusarium wilt of muskmelons and watermelons has invaded the chief melon-growing area of Essex County in southwestern Ontario. Survey records have shown crop losses amounting to 75 per cent on several farms.

Greenhouse tests showed that isolates from muskmelon were capable of attacking watermelon seedlings and, conversely, that isolates from watermelon caused some wilting of muskmelon seedlings. Isolates from muskmelon proved capable of causing wilt of watermelon up to 35 days after seeding in infested soil. The virulence of any isolate was appreciably greater on its original host than on the other host.

Seed treatment with thiram provided protection against pre-emergence rot but was incapable of preventing early post-emergence wilt.

The 6 isolates from muskmelon tested were observed to be morphologically and pathogenically alike. In contrast, the 3 isolates from watermelon differed sufficiently in virulence on watermelon seedlings to be regarded as different physiologic strains.

ACKNOWLEDGMENT

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A STRAIN OF TOBACCO MOSAIC VIRUS CAUSING VASCULAR NECROSIS AND WILT OF TOBACCO IN ONTARIO[1]

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During the first week of August, 1949, a virus disease was discovered in a tobacco field near Ridgetown, Ont., with symptoms strikingly different from those of all others previously reported or observed on tobacco in Ontario. Subsequently, it was found sparsely distributed in other areas of the burley tobacco belt. The virus proved to be a strain of tobacco mosaic (TM). Because of the severe nature of the disease, it seems desirable to call attention to its presence in Ontario on tobacco. The present paper describes the disease and gives an account of some preliminary studies on it.

LITERATURE REVIEW

There are numerous reports in the literature of strains of TM virus that induce necrosis in tobacco and tomato plants. In 1927, James Johnson (6) described a stem necrosis of tomatoes caused by a strain of TM. E. M. Johnson (5) described a "white mosaic" of burley tobacco which caused a necrosis of the leaves and necrotic streaks in the stem. Ainsworth *et al.*. (1) found that tomato streak in Canada and England was usually caused by a single TM strain (tomato streak virus 1). Smith (8) described a variant of tomato streak which caused only a mild mottle in tomato but a necrotic spotting and streak symptoms in White Burley tobacco.

Berkeley (2) compared the tomato streak strains occurring in Canada and England. Both strains caused primary necrotic lesions in several tobacco varieties and primary yellow lesions in others. The English strain caused the death of several varieties of tobacco in the field, whereas the Canadian strain caused primary necrotic lesions, followed by a systemic mottle. Jensen (4) has described a strain of TM that causes necrosis in tobacco and tomato, and two mutants derived from it. Köhler and Panjan (7) discovered in Germany a strain of TM that induces primary necrotic lesions in White Burley, with no secondary symptoms.

Valleau (10) and Valleau and Johnson (11) showed that varieties of burley and dark tobacco could be divided into two distinct groups based on their reaction to certain TM strains. One group responded with primary necrotic lesions, and streak if the virus became systemic, whereas the other group of varieties responded to the same strains with a systemic mottle. They designated the simple dominant gene controlling this necrosis response as N′ to distinguish it from the N gene from *Nicotiana glutinosa*, which has been transferred to several varieties of tobacco. Valleau and Johnson (11) found that the plantago strain (3) of TM caused necrosis and a streak disease in the N′ burley varieties in the field and a mottle on the n′ varieties.

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PLATE I

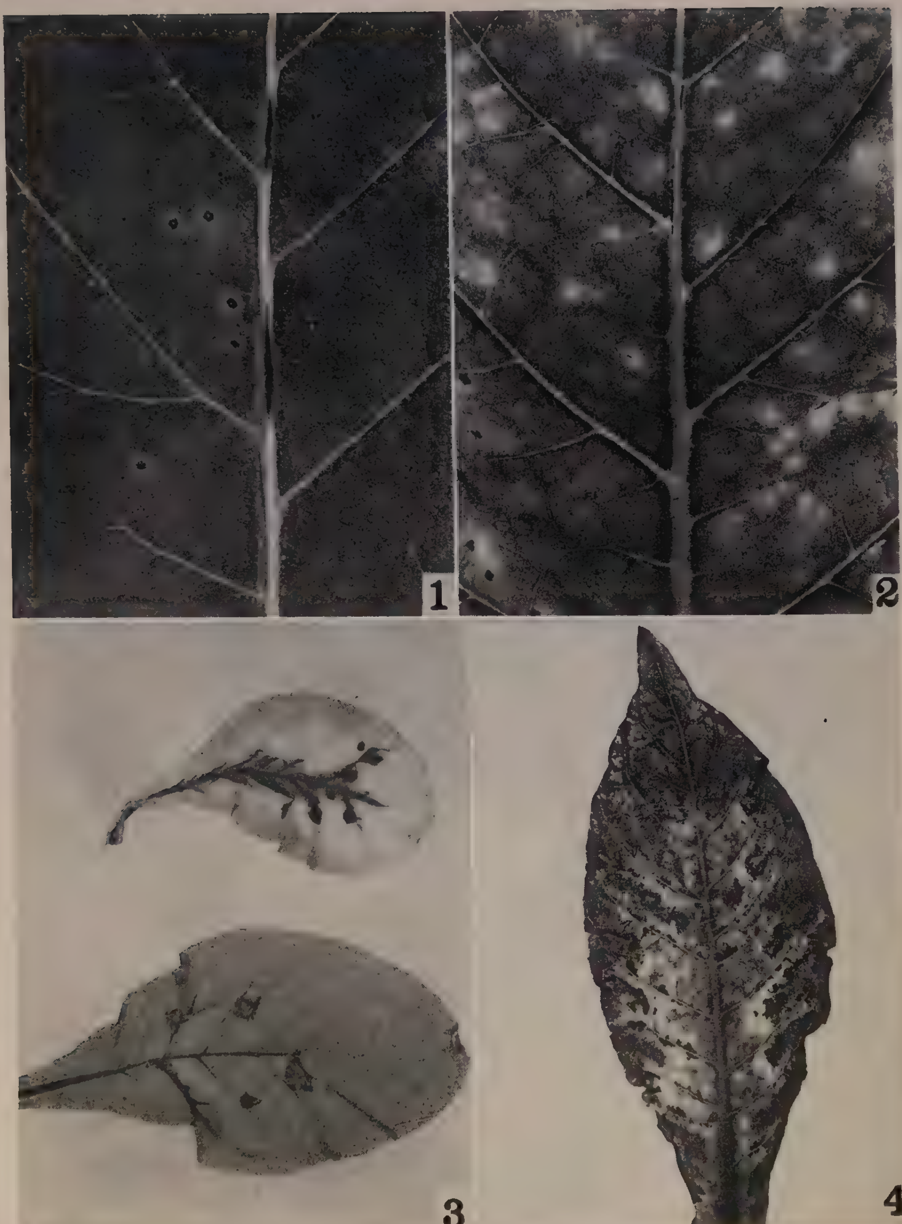

FIGURE 1. Primary necrotic lesions and veinal necrosis in Green Briar in the field. Inoculations made by rubbing with the Ontario strain; photograph made 5 days later.

FIGURE 2. Primary chlorotic lesions in Harrow Velvet in the field (a few of the lesions are slightly necrotic). Inoculated by rubbing with the Ontario strain.

FIGURE 3. Systemic necrosis in leaves of White Mammoth inoculated in the greenhouse by rubbing with the Ontario strain.

FIGURE 4. Mosaic mottle caused by the Ontario strain in Harrow Velvet in the field.

PLATE II

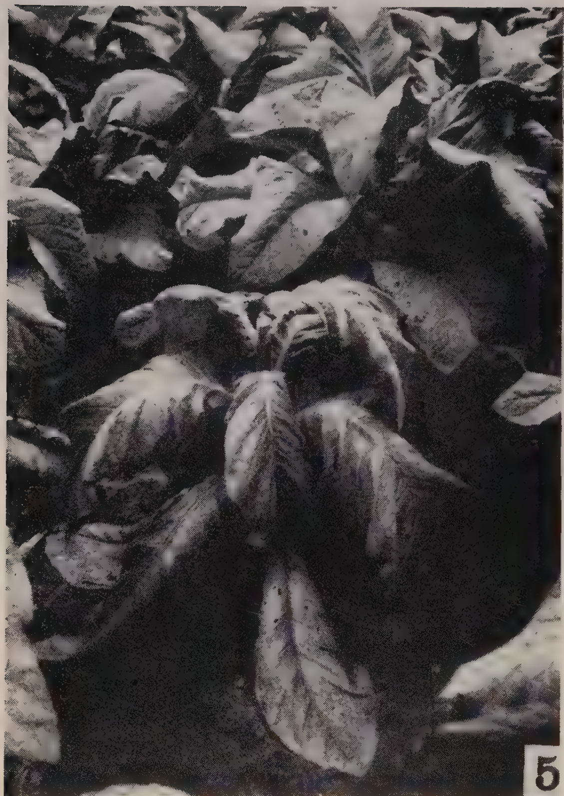

FIGURE 5. A naturally infected plant of the Greenwood variety on the Ridgetown farm. Note the wilting symptom and the absence of external necrosis.

FIGURE 6. A plant of Green Briar four weeks after inoculation in the field by patch grafting; systemic necrosis and death resulted. External necrosis was pronounced and there were no initial symptoms, as illustrated in Figure 5.

SYMPTOMS

Throughout the field of dark tobacco of the Greenwood variety at Ridgetown were found plants in various stages of wilting. Affected plants showed symptoms ranging from incipient wilt, with only one or several leaves drooping, to complete collapse and death of the plants (Figure 5). No additional external symptoms were apparent. However, an examination of internal tissues revealed the presence of necrosis and discoloration of the vascular tissue in some parts of affected stalks and petioles. All infected plants died prematurely and produced no suckers, because the roots became entirely necrotic. Thus, the typical field symptoms of this disease consisted of extreme wilt accompanied by varying degrees of internal necrosis. It should be mentioned, however, that inoculations to date have so far failed to reproduce the extreme wilt symptoms mentioned above.

Inoculations were carried out in the greenhouse on a wide range of hosts in the genus *Nicotiana*. Inoculations on *N. tabacum* resulted in primary necrotic lesions after 48 hours (Figures 1, 3), followed in some instances by systemic necrosis in the varieties Green Briar, White Mammoth, Yellow Mammoth, Delcrest, Greenwood, Samsun, and Kelley. Systemic necrosis readily developed in young, rapidly growing plants of these varieties when inoculated in the greenhouse. Field inoculations on plants of the above varieties in the flower bud stage, however, rarely resulted in systemic necrosis. Necrosis commonly developed along one side of the petiole of plants inoculated in the field and often occurred for short distances along their stalk. Nevertheless, systemic necrosis and death of the plant usually resulted from patch grafts at the base of the stalk (Figure 6). Species of *Nicotiana*, such as *N. sylvestris*, *N. longiflora*, *N. glutinosa*, *N. langsdorfii*, *N. sanderae*, *N. bigelovii*, and *N. rustica*, that respond with primary necrotic lesions to all or most strains of TM were even more severely affected by the new Ontario strain, and were often killed as a result of systemic necrosis.

Inoculations with the Ontario virus resulted in primary yellow or slightly necrotic lesions (Figure 2), followed by a typical chlorotic mosaic mottle (Figure 4), in the following varieties: Little Crittenden, Harrow Velvet, Haronova, Halley's Special, Judy's Pride, Kentucky White Burley, and Connecticut Havana 38. Savoying, stunting, and severe distortion consistently developed on young, rapidly growing plants of these varieties.

Occasionally, the virus was not limited to the necrotic areas on N′ N′ varieties that responded with primary necrotic lesions. In a few instances, a systemic mottle, with distortion, appeared in these varieties after the development of extensive necrosis. The mottle symptom often occurred on the sucker growth of Green Briar after old infected plants were cut back. The factors causing an alteration of the necrosis response in the latter variety, or a change in the virus, are not known. The virus mutated, but its capacity to cause a necrotic spotting on certain varieties was not lost. The necrosis response of the host appeared to be altered also by the presence of another virus. For example, the necrosis-responding variety Delcrest was systemically infected with two strains of the tobacco etch virus. Delcrest is one of a group of varieties that responds to the etch virus in the

greenhouse with only a mild mottle (9). Inoculation of these etch-infected plants with the Ontario necrosis-producing strain of TM resulted in the appearance, several weeks later, of a systemic mottle and distortion of the TM type. Primary lesions were sparse or absent and necrosis was often absent. The necrosis-producing strain of TM was readily recovered from the systemically-infected leaves. It appears, therefore, that the presence of another virus may alter the host reaction from necrosis to non-necrosis.

Inheritance of the Necrotic Response in N. tabacum

It would appear likely that the varieties responding to this virus with necrosis carried the N′ gene described by Valleau and Johnson (11) and that the varieties that did not thus respond carried the recessive n′ gene. To test this mode of inheritance (10), varieties of the former group were crossed with varieties of the latter group, and the F_1 and F_2 were inoculated with the Ontario virus. The crosses made were as follows:

Group N′ N′		*Group n′ n′*
1. Delcrest (flue cured)	×	Little Crittenden (dark)
2. Delcrest	×	Harrow Velvet (burley)
3. Delcrest	×	Halley's Special (burley)
4. Green Briar (burley)	×	Harrow Velvet
5. Green Wood (dark)	×	Little Crittenden

The F_1 of all crosses developed necrotic spots to a greater or less extent. After 7 days, however, a systemic mottling developed in the young expanding leaves of the heterozygous (N′ n′) F_1 plants. The leaves inoculated collapsed as a result of necrosis, but the newly developed leaves manifested typical mosaic mottling without necrosis. These heterozygous (N′ n′) F_1 plants did not die as a result of systemic necrosis, and systemic mottling invariably developed. In contrast, the homozygous N′ N′ plants rarely manifested systemic mottling without accompanying necrosis, after the formation of primary necrotic spots on the inoculated leaves. In many N′ N′ plants the virus was completely localized in these primary necrotic spots. If the virus became systemic in these N′ N′ plants, they often died as a result of vascular necrosis.

The response of the heterozygous (N′ n′) plants suggests that the N′ gene is not completely dominant. That is, the homozygous (N′ N′) condition is necessary to prevent the development of a systemic mosaic mottle. If this is the case, then F_2 plants should segregate in a ratio of 1 with necrosis (N′ N′) to 2 with necrosis and a systemic mosaic mottle (N′ n′) to 1 with a systemic mosaic mottle (n′ n′). Preliminary tests of the F_2 populations indicate that this segregation ratio is obtained. Further tests are being conducted with F_2 and F_3 populations in order to confirm the above results. As previously stated, in a few instances N′ N′ plants have developed a systemic mottle without accompanying necrosis. The cause of this altered response and the effect of environment on it is not known. It is not likely, however, that this non-gene controlled response is of sufficient frequency to alter significantly the genetical segregation ratios.

A Yellow Mutant of the Necrotic Tobacco Mosaic Strain

The Ontario strain induced leaf curl, distortion, and a dark green mottling in Bonny Best tomato. One inoculation on tomato from tobacco resulted in the development of a bright yellow mottle. Subsequent transfers of this yellow strain showed it to be similar to the original strain in its capacity to induce severe necrosis in the N′ tobacco varieties. However, the mottle in tomato and the n′ tobacco varieties was bright yellow in contrast with the greenish-yellow mottle caused by the original virus.

Comparison of the Ontario Strain with Other TM Strains Causing Necrosis

K. M. Smith sent the author 5 TM strains, including Aucuba mosaic, that caused necrotic primary lesions in the N′ varieties. All of the strains, except one designated 644B, caused less necrosis than did the Ontario strain. Symptoms produced by these milder strains were usually confined to the primary lesions on the N′ N′ varieties, and only occasionally became partly systemic by moving down the leaf petiole and part of the stalk, causing necrosis of these tissues. They did not at any time result in the death of the plant. A "mild green strain", obtained from James Johnson, behaved similarly. The "paramosaic strain" described by Köhler and Panjan (7) proved to be more virulent than Smith's strains, but did not approach the Ontario or Smith's 644B strain in virulence. Smith's strain 950 caused a systemic mild mottle several days after the development of primary lesions in all the N′ N′ varieties. Smith's strains 644A, Aucuba, and IVG remained localized in the inoculated leaf of the N′ N′ varieties, and no mottle developed. A field strain of TM that does not cause necrosis protected all the N′ varieties from the strains that cause primary lesions. Aucuba, 950, paramosaic, and Johnson's mild green strain could be readily distinguished from one another by the different types of mottling that developed in commercial varieties of tobacco, such as Harrow Velvet and Little Crittenden. The mottle and distortion caused by strain 644B in the n′ varieties were not so severe as that caused by the Ontario strain. Both of these strains caused a more severe distortion in the n′ varieties than did the other strains.

DISCUSSION

The virus described in this paper differed from many of the previously described "streak" strains of TM in that it caused no necrosis in tomato. Also, most of the other strains of TM tested that produce primary necrotic lesions in the N′ varieties cause less necrosis than did the Ontario strain. The failure to reproduce by artificial inoculation all of the symptoms observed in the diseased plantation at Ridgetown, suggests that other than mechanical inoculations were involved in this outbreak. That insects were the agents involved is suggested by the following evidence: The external symptoms consisted of wilting only, infected plants were scattered at random through the field, and the virus was confined to the vascular and surrounding internal tissue. The virus was probably deposited in the vascular tissue by sucking insects and remained localized in this and surrounding tissue because of the strong tendency of the infected host cells to become necrotic. It was likely carried through the plant and into the roots by way of the phloem and xylem elements, causing extensive necrosis of surrounding tissue which resulted in wilting and death of the plant.

Studies on the inheritance of the response to this virus in *N. tabacum* indicate that the N′ gene is not completely dominant. Mosaic mottling rarely developed in N′ N′ plants. In contrast, on N′ n′ plants a typical mosaic mottle developed on newly formed leaves and the inoculated leaves usually collapsed as a result of necrosis which did not become systemic. If dominance is not complete, the F_2 should segregate in a ratio of 1 with necrosis (N′ N′) to 2 with necrosis and a systemic mosaic mottle (N′ n′) to 1 with a systemic mosaic mottle (n′ n′).

SUMMARY

A strain of tobacco mosaic capable of inducing a severe necrosis in tobacco varieties carrying the N′ N′ genes was observed in Ontario tobacco fields. This strain induced a chlorotic mosaic mottle, stunting, and distortion in tobacco varieties carrying the n′ factor. It gave rise to a mutant that differed from the parent strain in mottling characteristics on different hosts but that was still capable of causing primary necrotic lesions in the N′ varieties. Circumstantial evidence relative to the wilt symptom together with the absence of external necrosis in naturally infected plants, suggest that this virus is transmitted to tobacco by insects. The inheritance of the response of *N. tabacum* to this virus is described. It is of little economic importance at present.

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CLAM SHELL, LIMESTONE, AND OYSTER SHELL WITH AND WITHOUT INSOLUBLE GRIT AS A SOURCE OF CALCIUM FOR THE GROWING CHICKEN[1]

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Ground limestone and oyster shells are the most common sources of calcium for chickens and hens. However, other sources of calcium, such as clam shells, coquina shells, marl and egg shells have been used successfully, as well as pure chemicals such as calcium sulphate and calcium lactate. Calcium is an essential mineral for sound skeletal development during the early life of the chick. Since poultry rations are based on grains and their by-products which are low in calcium, a supplement high in calcium must be added to the ration to make up the deficiency. The generally accepted practice is to add supplementary calcium to an otherwise balanced ration so that a calcium to phosphorus ratio of about 2 to 1 is obtained for chick rations (16).

The growing chicken seems to be capable of utilizing most soluble calcium compounds for bone formation. Kennard (13) found that oyster shell was superior to limestone for bone development, but Bethke, Kennard and Kick (3), in extensive studies of different calcium compounds for growth and bone formation found that many compounds could supply the calcium necessary for proper bone development. Buckner, Martin and Insko (7), and Buckner and Martin (6), in similar studies showed that a number of pure and impure calcium compounds served as good sources of calcium for the growing chicken. Deobald *et al.* (9) studied the availability of calcium for bone formation from a number of calcium salts, and found that, except in the case of extremely insoluble salts, the calcium of all compounds studied was apparently equally available for bone formation.

Few studies are recorded comparing clam shells with other calcium compounds; but work by Hart and Halpin (10) indicates that clam shells are inferior to oyster shells or limestone for chicks.

The need of the growing chick for grit as well as calcium has been extensively studied. Jull (12) suggests that grit is not essential for the growing chicken. Bethke and Kennard (2), Riedel (15), and Buckner, Martin and Peter (8) could find no benefit from feeding grit to growing chickens. Tepper, Durgin and Bottorff (17) conclude that grit is not essential for the first four weeks of growth. On the other hand Bird *et al.* (4) present evidence which indicates that poor growth is associated with lack of grit. However, Heuser and Norris (11) found that granite grit had no effect on the eight-week weight of cockerels, but that larger gizzards resulted, an observation confirmed by Platt and Stephenson (14). Blount (5), in a review of the effect of grit on the health of birds, questions the practice of feeding grits, both soluble and insoluble, to growing chickens.

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Table 1.—Per cent calcium and insoluble material in calcium supplements and insoluble grit

	Per cent calcium	Per cent insoluble material
Oyster shell	38.2	Nil
Clam shell	38.6	Nil
Limestone	39.8	0.6
Insoluble grit	Nil	98.9

The work reported herein was designed to study the relative value of ground limestone, clam shells and oyster shells, with and without insoluble grit, as sources of calcium for the growing chicken. The calcium supplements were all products of the Maritime Provinces of Canada. The oyster shell was a good quality shell supplied by Gillis Brothers, Orangedale, Victoria County, Nova Scotia. The clam shell was supplied by the Sea Foods Limited, Musquodoboit Harbour, Nova Scotia, and the limestone was from quarries at Admiral Rock in Hants County, Nova Scotia. All these products, particularly limestone, are available in considerable quantity in the Maritime area. The main purpose of this study was to determine if these local products could be successfully used as a source of calcium for growing chickens. The chemical analyses are given in Table 1, and indicate that the calcium supplements are all high in calcium and that the insoluble grit was of good quality. The limestone was a non-dolomitic, high grade limestone, and the insoluble grit was a high grade silicate grit.

EXPERIMENTAL

Eight groups of day-old Barred Plymouth Rock male chicks were selected at random from a uniform group of male chicks. Each group, consisting of 28 chicks, was placed in a deck of an electrically heated battery brooder. The chicks were wing-banded for individual identification. The four treatments were randomized among the eight groups of chicks. Each treatment was replicated once. The treatments consisted of adding 1 per cent of the finely ground calcium compound under study to a good chick

Table 2.—Composition of basal mash

	Pounds
Ground yellow corn	25.0
Ground heavy oats	20.0
Wheat shorts	20.0
Wheat middlings	20.0
Dehydrated alfalfa leaf meal	5.0
White fish meal	5.0
Soyabean oil meal	3.0
Dried buttermilk	2.0
Bone meal	1.0
Salt	0.5
Cod liver oil (200 D)	0.25

starter ration, balanced in all respects except as to calcium. The composition of the basal mash is given in Table 2. The four treatments were as follows, 1 per cent of the finely ground calcium supplement being added to the basal ration in each case—(1) oyster shells; (2) clam shells; (3) ground limestone; (4) oyster shells with insoluble grit fed *ad lib.* The chickens were allowed free access to feed and water at all times.

The chicks were weighed individually at the commencement of the experiment and at the end of the second, fourth and sixth weeks. Feed consumption for each group was recorded weekly. At the termination of the experiment, 10 birds from each group were chosen at random and sacrificed for bone ash analysis and gizzard weight and volume measurements.

The bone ash determination was carried out according to the A.O.A.C. method (1). The gizzards were removed, freed from all extraneous material, cleaned of their contents, dried in a towel and weighed. The volume of the gizzard was determined by measuring the amount of water displaced by the gizzard.

The data were analysed by methods of variance and covariance, the mean final weight being adjusted to a common food intake by covariance analysis.

RESULTS AND DISCUSSION

The mean bi-weekly gains in weight and the mean total gain per bird are shown in Table 3. In all cases the group fed the limestone supplement made the greatest gains. Statistical analysis of the individual final weight data reveals a significant difference (P .05) between the mean final weight of the group fed the limestone and the groups fed the oyster shells and clam shells. The latter are significantly lighter than the limestone group, but

Table 3.—Mean bi-weekly gains in weight (gm.)

Treatment	Number of birds	Initial weight	At end of week			Mean total gain
			2	4	6	
Oyster shell	53	41.1	68.3	166.8	286.3	521.4
Clam shell	55	40.8	68.8	167.5	291.2	527.5
Limestone	53	41.3	72.5	181.6	310.7	564.8
Oyster shell and grit	55	41.6	72.4	166.9	302.9	542.2

Table 4.—Mean feed consumption per chick to six weeks (gm.)

Treatment	At end of week			Mean total feed consumed
	2	4	6	
Oyster shell	180	479	859	1518
Clam shell	182	482	854	1518
Limestone	183	493	885	1561
Oyster shell and grit	198	482	871	1551

Table 5.—Observed and adjusted mean final body weights

Treatment	Observed	Adjusted*
Oyster shell	562	566
Clam shell	568	572
Limestone	606	602
Oyster shell and grit	584	581

* Observed means adjusted for regression of body weight on feed consumption.

the differences between these groups and the group fed the oyster shell and insoluble grit are non-significant. The difference between the limestone group and the group fed oyster shell and insoluble grit is also non-significant.

The mean bi-weekly feed consumption per bird is shown in Table 4, and it will be noted that the treatments showing the greatest gains in Table 3 also show the greatest feed consumption. It would appear that, for some reason, the limestone, and the oyster shell with grit supplements, improved the appetite, leading to increased feed consumption. When these differences in feed consumption are taken into consideration and the mean final body weights are adjusted for the regression of body weight on feed consumption, the differences between the adjusted mean final body weights are non-significant. The observed and adjusted mean final body weights are shown in Table 5. The observed significant differences in final body weights must, therefore, be attributed to differences in feed consumption and not to any of the calcium supplements used.

The calcium-to-phosphorus ratio of the rations was the same for all treatments, being 1.85, 1.87 and 1.88 for the oyster shell, clam shell, and limestone supplements respectively. On the basis of the adjusted mean final body weights it would appear that all calcium supplements studied may serve as good sources of calcium for the growing chicken.

Table 6.—Average per cent ash of tibia and average volume and weight of gizzard

Treatment	Per cent ash in tibia		Volume and weight of gizzard			
	Number of birds	Per cent ash	Number of birds	Volume ml.	Weight (gm.)	Weight of birds (gm.)
Oyster shell	20	42.3 ± 1.53*	13	19.0	18.9	561.5
Clam shell	20	42.3 ± 1.66	14	20.7	19.6	565.4
Limestone	20	43.1 ± 1.72	3	25.0	23.8	604.3
Oyster shell and grit	20	42.7 ± 1.67	18	23.5	22.3	597.7

*Standard deviation.

A summary of the bone ash and gizzard measurements are given in Table 6. The percentage of bone ash is quite satisfactory and there are no significant differences between treatments, indicating good and uniform bone development by all of the calcium supplements studied. Grit apparently had no effect on bone development.

Gizzard measurements, both volume and weight, show the same trend, increasing in the order of treatments, 1-2-4-3. The limestone supplement gives the largest and heaviest gizzards, but, due to an error, only three birds were measured in this group. The chickens on the oyster shell and grit supplement show larger and heavier gizzards than the chickens on oyster shells alone or clam shells. It will be noted that the average weight of the birds receiving the oyster shell plus grit is slightly greater than that of the birds receiving oyster shells or clam shells as sources of calcium. However, the difference in the mean final weights of these groups is non-significant, and the difference in the weight of the birds receiving grit and those not so treated is not great enough to account for the increase in size of the gizzard shown by the birds receiving grit. The feeding of grit seems to enhance the development of the gizzard. This is in agreement with the results of Heuser and Norris (10). While there is some evidence that the birds receiving limestone had larger gizzards than the birds on the other treatments, too few measurements were recorded to draw any definite conclusions. There is no significant difference between the oyster shell and clam shell treatments, in this respect.

The treatments did not have any adverse effect on the general health of the birds. The mortality was 3, 1, 3 and 1 chickens, respectively for treatments 1, 2, 3 and 4, indicating no apparent discrepancy in this regard between the different sources of calcium studied.

SUMMARY

1. Oyster shells, clam shells and limestone all served as good sources of calcium for the growing chicken.

2. The feeding of insoluble grit, in addition to oyster shells, had no effect on growth or bone development.

3. The three calcium supplements studied served as good sources of calcium for bone development.

4. Heavier and larger gizzards were developed in birds which received insoluble grit as compared with those not receiving insoluble grit.

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MANGANESE DEFICIENCY IN PEACH AND APPLE IN BRITISH COLUMBIA[1]

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INTRODUCTION

This paper reports the occurrence of a manganese deficiency in peach and apple in the Summerland district of British Columbia, the results of control experiments, and the manganese content of tissues from affected, non-affected, and treated trees.

The literature covering the role of manganese in the growth of agricultural plants is quite extensive, and a number of papers from various parts of the world deal specifically with the relation of this element to the growth of fruit trees in Australia (5, 10), England (4, 7, 11, 13, 14), New Zealand (1), South Africa (6), and the United States (2, 3, 8, 9, 12, 15). No Canadian literature pertaining to manganese in fruit trees was found.

In a number of these papers the symptoms caused by a deficiency of this element have been described. Several of the investigators found only the characteristic chlorotic pattern in the leaves but Duggan (7), Kilpatrick (10), and Thorne and Wann (12) noted, in addition, a reduction in growth and yield, and in some cases the death of branches.

In many papers (1, 7, 10, 11, 12, 13, 14, 15) the results of control experiments have been reported. Soil applications were in most cases unsuccessful, but Wann and Thorne (15) effected a control by digging 2 pounds of manganese sulphate into the soil beneath affected trees. In another paper (12) these authors obtained control by digging the sulphate into the soil at the rate of 200–400 pounds per acre. Duggan (7) used barnyard manure without success. Injection of manganese sulphate in pellet or dry crystal form into the trunks or limbs was generally effective (7, 11, 12, 13, 14). This treatment in some cases prevented recurrence of symptoms for at least 3 years. Injections of manganese sulphate solutions were made by Duggan (7) and Epstein and Lilleland (8). The former obtained only slight recovery with the method, whereas the latter found it quite effective. Duggan (7) and others (1, 8, 10, 13) applied spray solutions of manganese sulphate in water. Duggan reported a slow and only partial recovery when they were applied to severely affected trees. The others experimenting with moderately affected trees obtained complete recovery with only one application.

The manganese content of normal and affected tissues has been reported by several investigators. Epstein and Lilleland (8) in a study of 39 samples of Elberta peach leaves reported a range of 293.2 to 21.1 p.p.m. for normal and 33.1 to 5.6 p.p.m. for affected. Wann and Thorne (15) obtained an

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average of 93.7 p.p.m. in leaves from two normal Chinese apricots and 25.0 p.p.m. from two affected trees and 25.0 and 3.1 p.p.m. from normal and affected peach. Beattie and Ellenwood (2), in a survey of the nutrient status of non-affected Ohio apple trees, obtained a wide range in manganese content. Leaves of Stayman Wincsap had from 120.0 to 20.0 p.p.m. and of Delicious from 156 to 20.0 p.p.m. Kenworthy (9), investigating the value of leaf analyses in diagnosing nutrient requirements of fruit trees, listed the ranges of manganese content as follows: apple, 200 to 38 p.p.m., peach 270 to 17 p.p.m., cherry 280 to 45 p.p.m., and pear 220 to 68 p.p.m. In no case was there any abnormality which could be attributed to a deficient or an excessive amount of manganese.

SYMPTOMS

The symptoms as they occur in British Columbia agree with those described as being caused by a moderate manganese deficiency (3, 10, 12, 15). Initially, small irregularly shaped spots, light green in colour, appear in the marginal and interveinal areas of the leaf, and give it a mottled appearance. Gradually these areas become more generally affected, while the areas immediately adjacent to the midrib and main veins remain a normal green. This gives the leaf a very definite and characteristic colour pattern. In observations to date no measurable reduction in leaf size has occurred, nor has there been any effect on length of twig growth or crop yield. The symptoms on peach and apple are illustrated in Figures 1 and 2 respectively. The condition has been observed casually over a period of several years, but it was not until the summer of 1950 that a manganese deficiency was suspected. No general survey has yet been made, but the disorder is known to occur in several orchards on peach, apple and apricot in the Trout Creek area of the Summerland district.

INVESTIGATION

Control Experiment and Results

On July 18, 1950, 6 plots, each of 4 affected Elberta peach trees about 8 years old, were marked out and 5 were sprayed with the following materials in 100 gal. water: *Plot 1*, 1 pound each of boric acid, manganese sulphate, ferrous sulphate, and zinc oxide; *Plot 2*, 2 pounds boric acid; *Plot 3*, 2 pounds zinc oxide; *Plot 4*, 2 pounds manganese sulphate; and *Plot 5*, 2 pounds ferrous sulphate. *Plot 6* served as check. The applications were made with a standard spray gun at approximately 300 lb. pressure.

The plots were examined in August. The leaves on trees in Plots 1 and 4 by this time had completely recovered (Figure 1) while those on the other plots remained unchanged. No injury was apparent from any of the treatments.

Analyses and Results

Leaf samples were taken from each tree in the above plots 3 months after treatment and from several non-affected trees growing in separate localities. Leaf samples were also taken from similarly affected apple trees growing in an orchard adjoining the plots and from non-affected trees in other orchards. The periodate method for the determination of manganese was used.

FIGURE 1. Elberta peach leaves. The centre three leaves show varying degrees of manganese deficiency. The one on the right is from a healthy tree. The one on the left is from an affected tree sprayed with manganese sulphate.

FIGURE 2. McIntosh apple leaves. The four on the right show varying degrees of manganese deficiency. The leaf on the left is from a healthy tree.

TABLE 1—THE MANGANESE CONTENT OF ELBERTA PEACH LEAVES. (P.P.M. ON A DRY WEIGHT BASIS)

Plot No.	Treatment	No. of Samples	Condition of Leaves	Manganese Content		
				High	Low	Average
I	Sprayed 1 lb./100 gal. B, Mn, Fe, Zn	4	Green	76.5	44.0	56.7
II	Sprayed 2 lb./100 gal. H_3BO_3	4	Chlorotic	24.2	14.2	16.9
III	Sprayed 2 lb./100 gal. ZnO	4	Chlorotic	13.2	9.2	11.4
IV	Sprayed 2 lb./100 gal. $MnSO_4$	4	Green	68.0	48.0	57.1
V	Sprayed 2 lb./100 gal. $FeSO_4$	4	Chlorotic	24.2	10.2	14.9
VI	No treatment	4	Chlorotic	10.5	8.2	9.3
Check	Different orchard	8	Green	51.5	24.5	40.9

TABLE 2—THE MANGANESE CONTENT OF APPLE LEAVES. (P.P.M. ON A DRY WEIGHT BASIS.)

Variety	Orchard	No. of Samples	Condition of Leaves	Manganese Content		
				High	Low	Average
McIntosh	Gartrell	1	Chlorotic	12.0	—	—
"	Thornber	4	Chlorotic	10.5	6.5	8.5
"	Expt. Sta.	10	Healthy	145	54.5	81.6
Newtown	Thornber	4	Chlorotic	15.5	10.7	13.2
"	Kanz	2	Healthy	116	70.0	93.0
"	Expt. Sta.	12	Healthy	150	48.5	81.8
Delicious	Kanz	5	Healthy	160	58	114
"	Expt. Sta.	4	Healthy	123	50	78

The results of analyses on peach leaves are presented in Table I, and those on apple leaves in Table 2. Normal peach leaves contained from 51.5 to 24.5 p.p.m. and affected leaves from 10.5 to 8.2 p.p.m. The content of the sprayed leaves, 3 months after treatment, was from 76.5 to 44.0 p.p.m., but some spray residue may have been present. Normal apple leaves contained from 160.0 to 48.5 p.p.m. and affected leaves from 15.5 to 6.5 p.p.m. These results are in general agreement with those of other investigators for cases of moderate manganese deficiency.

SUMMARY

1. The occurrence of a manganese deficiency in the Okanagan area in British Columbia is recorded.

2. Foliage symptoms, characteristic of moderate deficiency, were observed on peach, apple, and apricot.

3. One spray of manganese sulphate solution effected complete recovery on peach in 1 month's time.

4. Manganese content of normal peach leaves averaged 40.9 p.p.m. and affected leaves 9.3 p.p.m. Corresponding figures for apple were 86.8 and 10.8 p.p.m.

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QUALITY OF AUSTRALIAN WHEAT VARIETIES GROWN IN CANADA[1]

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INTRODUCTION

Three years ago, a number of miscellaneous samples of Australian varieties of bread wheat were submitted to this laboratory for testing. Several of these had excellent baking strength and interesting dough properties, quite different from those of Canadian varieties of comparable strength. Arrangements were then made to grow eight of the Australian varieties, together with Marquis and Thatcher, at four stations in Western Canada, so as to obtain material for a strict comparison of varieties. A similar set of Australian varieties, grown at a single station in New South Wales, was also obtained. This paper presents the results of studies of the varieties. Agronomic data are included, together with information obtained in milling, baking and other tests of bread making quality.

The first section of the paper deals with tests on the varieties grown in Canada. In addition to agronomic data, there are sections on grade, milling and chemical data, on baking data, and on measurements of the physical properties of the doughs made with the farinograph and the extensograph. The second section deals with the varieties grown in Australia. Although the quality tests made were as extensive as those for the varieties grown in Canada, only the more important data are presented and discussed.

VARIETIES GROWN IN CANADA

The wheats studied were the Australian varieties Gabo, Kendee, Bencubbin, Celebration, Charter, Gular, Yalta, and Cailloux. Canadian varieties included for comparison were Marquis and Thatcher. Marquis is the varietal standard of quality for the three top Canadian grades, and Thatcher is a stronger rust-resistant variety, which is grown extensively in the Prairie Provinces and makes up over 50 per cent of all the wheat currently exported.

The varieties were grown in rod rows at Brandon, Manitoba; at Indian Head and Swift Current, Saskatchewan; and at Lethbridge, Alberta. These four stations are widely separated as to geography and climatic conditions. All the varieties were seeded in May and were harvested in late August or early September, 1949.

Agronomic Data

Agronomic data for the 10 varieties, supplied by the Dominion Laboratory of Cereal Breeding, are given in Table 1. The data are mean values for the two or more stations at which the tests were made. Yield per acre, days to ripen, and height, were measured at all four stations; resistance to lodging was measured at three stations, and leaf rust resistance at two.

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TABLE 1.—AGRONOMIC DATA

Variety	Yield per acre	Days to ripen	Resistance to lodging	Height	Leaf rust
	bushels			inch	%
Marquis	30.6	110.2	1.6	34.2	57.5
Thatcher	34.6	107.8	1.5	32.2	77.5
Gabo	34.3	109.0	1.1	28.4	0.9
Kendee	34.2	110.0	1.1	31.4	65.6
Bencubbin	33.8	109.6	2.5	32.8	87.5
Celebration	33.2	113.2	1.4	34.1	73.8
Charter	32.5	112.7	1.6	32.5	86.2
Gular	32.0	108.3	2.0	30.2	38.8
Yalta	30.8	112.2	1.2	32.7	90.6
Cailloux	26.3	108.4	1.1	30.3	88.8

None of the Australian varieties quite equalled Thatcher in yield per acre, although all except Cailloux outyielded Marquis. Differences in resistance to lodging are negligible, and all varieties are classed as having very strong straw. Gular and Cailloux were only a little later than Thatcher in days to ripen, but the other Australian varieties were a day or more later and several were later than Marquis. The almost complete resistance of Gabo to leaf rust is particularly noteworthy; Gular is also more resistant than either Marquis or Thatcher. Among the Australian varieties, Gabo and Gular gave the most promising results in these tests. Yalta and Cailloux were the least satisfactory; both are very susceptible to leaf rust. Yalta ripened late, and Cailloux gave the lowest yield.

Stem rust was not prevalent at the several stations where the varieties were grown in 1949, but several of the varieties were grown at Winnipeg in 1948 under an artificial rust epidemic. In that year, Gabo and Charter were only 2 per cent susceptible. Values for the other varieties were: Celebration, 10 per cent; Kendee, 20 per cent; Yalta, 30 per cent; Gular, 70-80 per cent; and Bencubbin, 90 per cent. Corresponding values for the Canadian varieties were: Marquis, 80 per cent; and Thatcher, 20 per cent.

Methods for Quality Tests

Composite samples of each variety were tested by methods commonly used for comparing Canadian varieties. The composite sample of each variety consisted of 945 g. from Brandon, 400 g. from Swift Current, 1300 g. from Indian Head, and 800 g. from Lethbridge.

The composite samples were milled to yield in an Allis-Chalmers laboratory mill at 15 per cent moisture after overnight tempering. Marquis and Charter, which was closest in bushel weight to Marquis, were selected as the standards for milling. The two standards were milled to give a satisfactory yield of long-patent flour of good colour, and resulting feed flours were used as colour standards for controlling the yields of the other samples.

Protein content ($N \times 5.7$) was determined by the Kjeldahl procedure, and yellow pigment content by the n-butyl alcohol method and Evelyn colorimeter. Baking quality was determined with the malt-phosphate-

bromate procedure (3) in three different ways. Firstly, each flour was baked by itself to obtain information on general baking quality; secondly, each flour was baked with equal parts of a low-protein flour (9.4 per cent), made up of 75 per cent English and 25 per cent Argentine, to obtain information on blending value; and thirdly, each unblended flour was baked with doughs mixed for 1, 1.5, 2, 2.5, 3, 3.5 and 4 minutes (1), to obtain information on mixing tolerances. For this last procedure, loaf volumes were plotted against mixing times and smooth curves were fitted to the data by statistical methods. Physical properties of the doughs were assessed from mixing curves made with the Brabender farinograph and by stretching curves made with the Brabender extensograph (2).

Grade, Milling and Chemical Data

The Australian varieties yielded wheats of a type not produced in Western Canada, and there is no grade class in the Canada Grain Act which applies. The wheats resemble white spring varieties like Axminster and Quality, but the Inspection Branch preferred to restrict the grades assigned to numbers only, based on bushel weight, kernel appearance, and soundness. All the varieties were classed as No. 1 or No. 2 wheats. Marquis graded No. 2 Northern and Thatcher graded No. 1 Northern.

Miscellaneous milling and chemical data are given in Table 2. The two Canadian varieties, which serve as standards for comparison, are listed first, followed by the Australian varieties in order of descending protein content.

Cailloux gave the highest bushel weight and was closely followed by Marquis. Gular, Charter, and Yalta were higher in bushel weight than Thatcher. Cailloux was also highest in protein content, and this variety and Gular exceeded Thatcher. Gabo was equal to Thatcher in protein content and above Marquis. All other Australian varieties had protein contents lower than that of Marquis.

All the Australian varieties milled freely and satisfactorily, and, in general, gave yields of long patent flour which compared favourably with those of Marquis and Thatcher. Yellow pigment of flour was lowest for

TABLE 2.—MILLING AND CHEMICAL DATA

Variety	Grade No.	Bushel weight	Protein		Flour yield	Flour ash	Yellow pigment	
			Wheat	Flour			Wheat	Flour
		lb.	%	%	%	%	p.p.m.	
Marquis	2 Nor.	66.5	13.7	12.8	72.6	0.44	3.46	2.19
Thatcher	1 Nor.	65.0	14.0	13.2	72.6	0.41	3.57	2.36
Cailloux	1	67.0	14.9	14.0	72.9	0.43	3.59	2.64
Gular	2	65.5	14.1	13.2	70.9	0.45	2.83	1.86
Gabo	2	64.0	14.0	13.0	71.7	0.44	3.00	2.04
Charter	1	66.8	13.3	12.5	72.3	0.48	3.72	2.03
Yalta	2	66.0	13.0	12.1	72.7	0.46	3.66	2.74
Celebration	1	64.0	12.9	12.0	72.7	0.48	3.87	2.60
Kendee	2	63.8	12.5	11.5	72.1	0.48	3.68	2.43
Bencubbin	2	63.5	11.2	10.0	71.5	0.46	3.94	2.72

Gular and next lowest for Gabo and Charter, but the remaining Australian varieties were all higher than either of the Canadian varieties. For laboratory milled flours, ash contents are quite satisfactory, but values are definitely higher for the Australian varieties than for Thatcher.

Baking Data

The data in Table 3 show all the important loaf qualities for the unblended flours. For the blended flours, loaf volumes only are given, since the supporting value of a wheat can be evaluated satisfactorily by this measurement. The blended flour loaves, however, were scored for other loaf qualities, and these will be mentioned where necessary.

TABLE 3.—BAKING DATA FOR UNBLENDED AND BLENDED FLOURS

Variety	Unblended flours						Blended
	Absorption	Flour protein	Loaf volume	Crumb colour*	Crumb texture*	Loaf appear.	Loaf volume
	%	%	cc.	Max. 10	Max. 10	Max. 5	cc.
Marquis	61.4	12.8	765	7-y	7-o	4.5	715
Thatcher	61.9	13.2	815	7-y	7-o	4.5	740
Cailloux	59.7	14.0	780	6-y	7-o	4.5	735
Gular	61.9	13.2	800	7-y	7-o	4.0	730
Gabo	62.8	13.0	790	5.5-gy	6-co	4.0	730
Charter	62.3	12.5	755	6.5-y	6.5-cl	4.5	710
Yalta	61.4	12.1	705	4.5-gy	5-co	4.0	685
Celebration	60.4	12.0	730	5-y	6.5-o	4.5	695
Kendee	58.0	11.5	700	5-gy	6.5-co	4.0	665
Bencubbin	52.2	10.0	590	3.5-gy	4-c	2.5	585

*y = yellow, g = greyish, o = open, c = coarse, cl = close.

The data for the unblended flours show that baking strength (loaf volume) parallels protein content quite closely, a relation which is usual for high grade wheat grown in Western Canada. None of the Australian varieties quite equalled Thatcher in loaf volume, but Cailloux, Gular, and Gabo were slightly better than Marquis, and Charter was about equal to it. Since Cailloux was almost 1 per cent higher in protein content than Thatcher, its slightly smaller loaf volume indicates inferior protein quality. On the other hand, Gular and Gabo are classed as equal in protein quality to Thatcher. The remaining Australian varieties are definitely lower in baking strength, particularly Bencubbin which is in a class apart from the other varieties. Excepting Gular, the Australian varieties were inferior to Marquis and Thatcher in internal loaf scores; crumb colour was more yellow or yellow with a greyish tinge, and texture was coarser and more open. Compared with the Canadian varieties, Gabo and Charter were higher in absorption, Gular and Yalta were about the same, Cailloux, Celebration, and Kendee were lower, and Bencubbin was very much lower.

The most noticeable difference in dough handling quality between the better Australian varieties and the Canadian wheat was in springiness and extensibility. The Canadian samples were typically lively, springy, and extensible. The Australian varieties were lively but less springy, more extensible and more malleable. The dough properties of the two classes of wheat are different but equally useful.

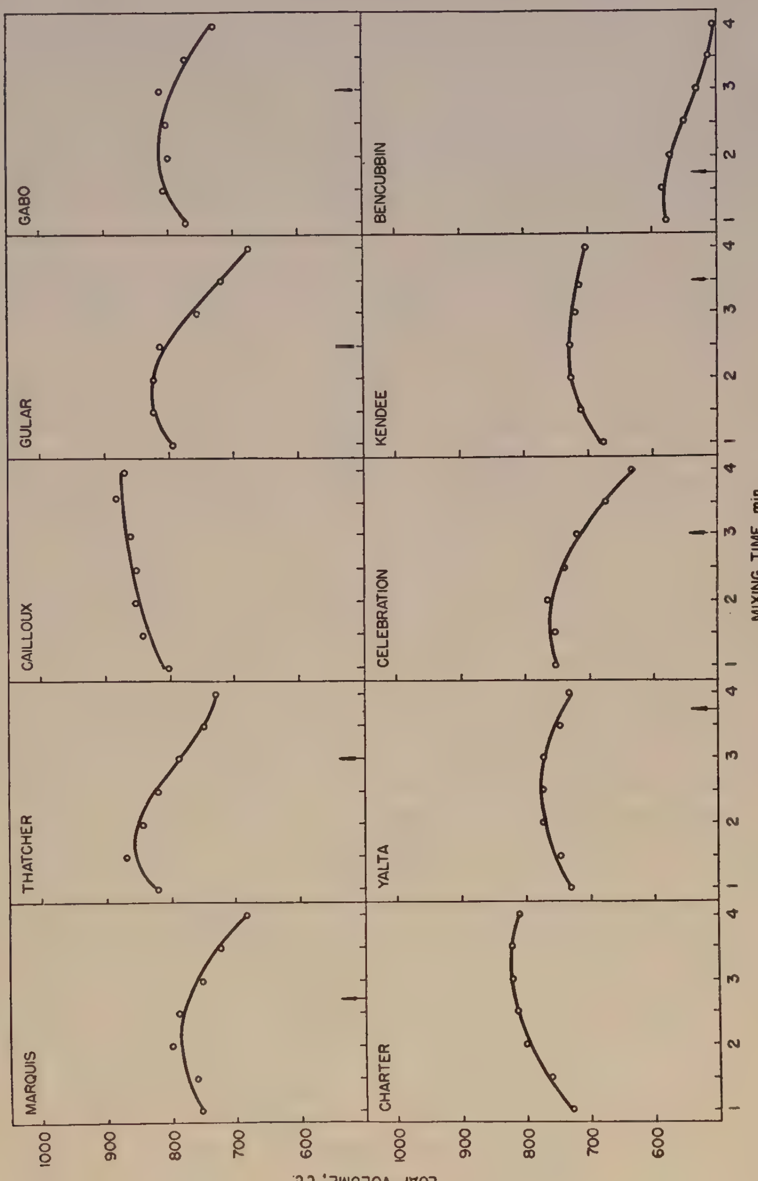

FIGURE 1. Curves for loaf volume on mixing time. The arrows indicate the times when the doughs became definitely sticky.

In evaluating varieties for blending with equal parts of a weaker sample such as was used in this study (protein, 9.4 per cent and loaf volume 560 cc.), a minimum loaf volume of 700 cc. for the blend flour can be taken as satisfactory for a good variety. Marquis, Thatcher, Cailloux, Gular, Gabo, and Charter met this standard. Yalta and Celebration did not quite qualify, but their loaf volumes were so close to 700 cc. that it would be unreasonable to fault them for this alone. But Yalta was also inferior in loaf appearance and crumb colour, and crumb colour for Celebration was much inferior to that of Marquis, Thatcher, and the better Australian varieties. Kendee is too far below the minimum loaf volume to be classed as a satisfactory blending wheat, and Bencubbin gave a loaf which was only a trifle larger than that of the weak flour with which it was blended.

Data for the mixing-time study are presented in Figure 1 as curves for loaf volume on mixing time. The arrows on the base lines show when the doughs out of the mixer were definitely sticky.

In evaluating the curves, the following points are considered: Mixing time over which initial loaf volume is maintained, which is considered a measure of mixing requirements and tolerance to mixing; difference between initial and maximum loaf volumes, which is considered a measure of reserve strength; general level of the curve, which indicates over-all baking strength; and time of mixing when definite dough stickiness is first observed. When the over-all level of a curve is low, the flour is faulted for low baking strength regardless of the curve shape. The curves for Marquis and Thatcher are first and second in the top half of Figure 1, and the curves for the Australian varieties follow in order of decreasing protein content reading from left to right.

The curves for Marquis and Thatcher are fairly typical; mixing tolerances are much the same, initial and reserve strength are greater for Thatcher, stickiness in the dough occurs at about the same time, and over-all baking strength is better for Thatcher. Only three of the Australian varieties resemble the Canadian varieties in curve type: Gular, Gabo, and Celebration. Gular is like Thatcher, but over-all strength is lower and stickiness in the dough occurs a little earlier. Gabo is like Marquis, but over-all strength is slightly better since the curve falls off less sharply towards the end. Celebration is like Marquis also but reserve strength and over-all strength are lower. The Yalta curve indicates very good reserve strength and mixing tolerance, but over-all strength is inferior to that of Marquis. Although the Kendee curve is flatter than that of Marquis, its general level is too low. The curve for Bencubbin is typical of a weak variety; over-all strength is very low, the curve falls off gradually from the beginning, and the dough became sticky with a short mixing time.

The curves for Cailloux and Charter are a type not yet found in Canadian varieties. Both curves rise gradually from the point of initial mixing, indicating exceptionally good mixing tolerance; there was no stickiness in the dough with any mixing time; over-all strength is good, particularly for Cailloux; and reserve strength is also good, particularly for Charter. Cailloux is a very strong variety that gives a good performance with both a short and a long mixing time, and over-all strength is better

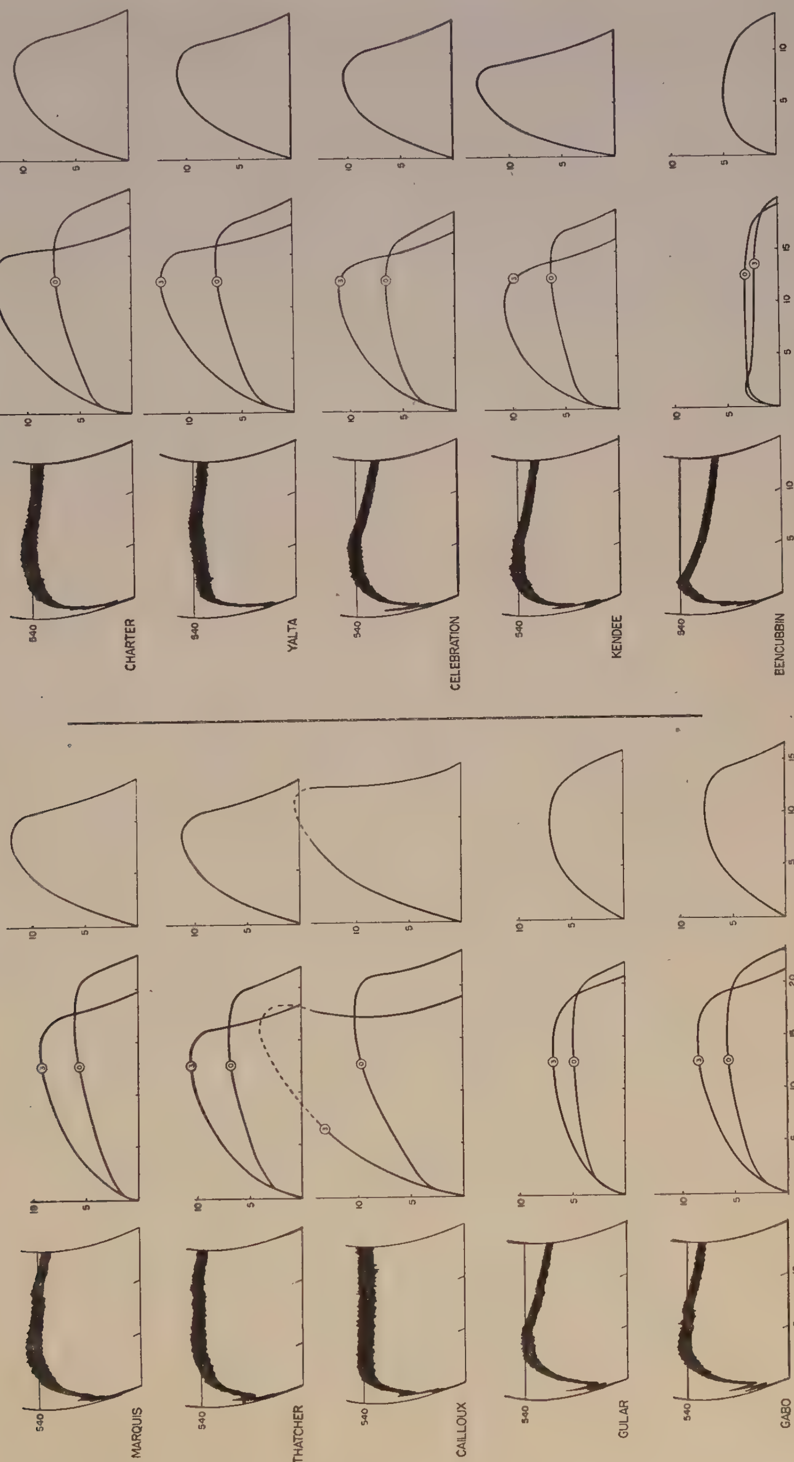

FIGURE 2. Farinograms (*left*), Extensograms for unfermented doughs (*middle*), and Extensograms for fermented doughs (*right*). The numbers on the middle Extensograms indicate milligrams of bromate.

than that of Thatcher. Charter is a variety that does well with a medium and a long mixing time but not with a short mixing time. At optimum mixing times Charter is not equal in baking strength to Thatcher.

Special mention should be made of the rapid recovery of the doughs of the Australian varieties when they became sticky with prolonged mixing. Even though quite slack when taken from the mixer the doughs were essentially normal a few minutes later and could be handled quite easily. Doughs from good Canadian varieties like Thatcher, with the same degree of stickiness, require a much longer time to recover their normal consistency, though they do recover fully and generally by the time the first punch is given (1 hour and 45 minutes).

It is apparent from the results of these different baking methods that Cailloux, Gular, Gabo, and to a lesser extent Charter, possess the all-round baking qualities of good strong varieties. They differ in some ways from Marquis and Thatcher, but the results do not mark them as being very much different for baking alone and for blending with weaker wheats. Of these four Australian varieties, Cailloux is judged to be the strongest, and Gabo and Gular the next strongest. Yalta, Celebration, and Kendee are not equal to Marquis or Thatcher in all-round baking performance, and Bencubbin is not a satisfactory bread making wheat when judged by Canadian standards.

Farinograms and Extensograms

Reproductions of the farinograms and extensograms are presented in Figure 2. Farinograms are at the left, extensograms for unfermented doughs are in the middle (upper curves show the effect of the addition of 0.003 per cent of potassium bromate), and extensograms for fermented doughs are at the right. The curves for the Canadian varieties are at the top (left) and the Australian varieties follow in order of descending protein content. Measurements taken from the curves are given in Table 4.

The farinogram can be evaluated by its general pattern and by the time in minutes (development time) required for the dough to attain

TABLE 4.—DIMENSIONS OF FARINOGRAMS AND EXTENSOGRAMS

Variety	Farinogram	Extensogram (unfermented)				Extensogram (ferm.)	
	Development time	No bromate		0.003% bromate		Length	Height
		Length	Height	Length	Height		
	min.	cm.	cm.	cm.	cm.	cm.	cm.
Marquis	5.25	23.4	6.0	19.8	9.2	14.0	11.9
Thatcher	6.50	21.7	6.8	18.2	10.5	13.6	11.1
Cailloux	4.00	23.3	10.2	19.1	19.2	15.0	15.7
Gular	5.00	22.0	5.0	20.9	6.7	16.1	6.9
Gabo	5.00	23.2	5.6	21.1	8.4	16.3	7.6
Charter	6.00	21.3	7.2	17.8	13.0	14.3	10.7
Yalta	8.50	20.2	7.2	18.0	12.4	13.9	10.8
Celebration	6.00	18.8	6.6	16.8	10.9	13.1	10.2
Kendee	4.50	18.8	6.2	16.0	10.7	11.8	13.0
Bencubbin	3.00	19.8	3.2	19.4	3.2	13.4	4.9

maximum development. This time corresponds to the distance along the base line measured from the beginning of the curve to its highest point at maximum width. For Canadian flours, development time is associated with potential strength and, generally, the longer the time the greater the strength, provided that the over-all pattern of the curve is satisfactory. A curve should rise fairly slowly, with a development time of about 5 to 6 minutes, and maintain its maximum height for most of the mixing period.

The extensogram can be evaluated by its total length along the base line and by its maximum height. Length of curve is proportional to the distance a dough stretches before it breaks and is a measure of extensibility. Height is a measure of the resistance the dough offers during stretching. A typical extensogram for a good Canadian unfermented dough is about 21 to 23 cm. long with a maximum height of about 5 to 7 cm. Maximum resistance (height) occurs near the end of the stretching. Addition of bromate to the dough generally reduces curve length and increases curve height. Similarly, a fermented dough curve is shorter and taller than the corresponding unfermented dough curve.

Among the Australian varieties which were considered to be the best by baking tests, Charter is the only one which gave a farinogram and extensogram similar to those of Marquis and Thatcher. Response to bromate, as indicated by the difference in height of the extensograms for the unfermented doughs, was greater, but otherwise curve patterns and measurements were not very different. The curves for Cailloux, the Australian variety of highest protein content, are unlike those of the Canadian and the other Australian wheats, and are types which do not occur among Canadian varieties. The wide farinogram maintains its maximum height for the full mixing time, the unfermented dough extensogram is the highest of the series, and response to bromate is very great. This great resistance to stretching of the dough is reflected in the fermented dough curve which is very high in relation to its length. While the Cailloux curves differ from any curves previously examined in this laboratory, the authors interpret them as representing a very strong wheat.

The curves for Gabo and Gular are very similar but are different from those of the Canadian varieties. The farinograms are narrower and fall off much more sharply after point of maximum consistency, the extensograms—unfermented and fermented doughs—are not nearly as tall (less resistance), and response to bromate is much less.

Among the other Australian varieties whose baking performance was not as good, some gave curves which resemble those of Marquis and Thatcher and others did not. The curves for Yalta are not markedly different from those of the Canadian varieties, although the farinogram rises more slowly and has a longer development time. In addition, the unfermented dough extensograms, with and without bromate, for Celebration and Kendee, are similar in type to those for Thatcher, but the farinograms for these two varieties fall off more sharply like that for Gabo. Although the fermented dough curve for Celebration is similar to that for Thatcher, that for Kendee is shorter and higher. All the curves for Bencubbin are typical of a weak variety and confirm its poor baking performance.

The most significant feature of Figure 2 is the similarity in curve types for the two Canadian varieties as compared with the wide range in types for the Australian varieties. Farinograms and extensograms for the principal varieties of Western Canadian hard red spring wheat eligible for the top Canadian grades generally show the same degree of similarity as is shown by the curves for Marquis and Thatcher. The physical properties of doughs are just as carefully controlled as are other important qualities such as protein content and baking behaviour. It is established practice to recommend for licensing and distribution only those varieties whose all-round qualities are similar to those of Marquis and other good varieties now in general use. Such a policy makes for uniformity of quality in shipments of wheat that are handled and transported in bulk and sold on the basis of a grade certificate.

VARIETIES GROWN IN AUSTRALIA

Samples of wheat grown in Australia represented Gular, Gabo, Charter, Yalta, Celebration, Kendee, and Pusa 4. Cailloux and Bencubbin were omitted from the series, but Pusa 4, a popular wheat grown in the northwest area of New South Wales, was included.

The varieties were grown at Temora, New South Wales, in 1948-49. Temora is situated in the southern part of the wheat belt at an elevation of between 500 and 1100 feet above sea level where average rainfall is between 12 to 14 inches, and the soil type is red-brown to red loam. The district lies westward of the Great Dividing Range about 150 miles from the coast. During harvest time it is not uncommon to experience shade temperatures of above 100° F. As seeding time is April and June, the Australian autumn, and harvest time is November and December, the crop is classed as winter wheat.

TABLE 5.—MISCELLANEOUS QUALITY DATA

	Pusa 4	Charter	Yalta	Celebration	Gular	Gabo	Kendee
Grade number	1	1	1	1	2	2	1
Bushel weight, lb.	63.8	64.0	65.2	66.0	61.2	60.0	63.8
Wheat protein, %	15.8	14.4	13.8	13.8	13.6	13.6	13.5
Flour yield, %	71.7	72.1	71.3	72.3	70.3	71.6	71.4
Flour yellow pigment, p.p.m.	1.95	1.49	2.45	2.24	1.50	2.10	2.10
Absorption, %	65.3	67.0	62.9	64.2	65.2	62.1	62.3
Loaf volume, cc.	885	815	780	805	805	805	775
Farinogram:							
Development time, min.	13.50	9.75	12.00	9.75	6.00	6.25	7.00
Extensogram (unfermented):							
Length, cm.							
No bromate	24.5	21.8	18.4	19.1	22.6	22.1	20.9
0.003 % bromate	19.8	18.0	15.7	17.3	18.9	18.4	16.1
Height, cm.							
No bromate	11.5	10.0	12.4	9.8	8.6	9.6	9.7
0.003 % bromate	19.6	15.0	18.3	13.2	12.8	15.7	16.2
Extensogram (fermented):							
Length, cm.	16.0	14.9	13.1	12.7	14.8	13.6	11.9
Height, cm.	14.7	11.6	14.6	11.3	11.1	12.6	15.5

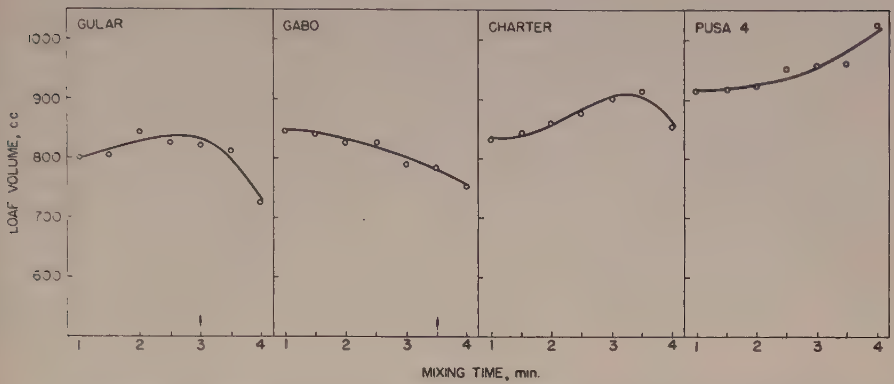

FIGURE 3. Curves for loaf volume on mixing time for Gular, Gabo, Charter, and Pusa 4. The arrows indicate the times when the doughs became definitely sticky.

After grading by Canadian standards, the seven wheats were milled, baked, and otherwise tested for quality by the same methods as were used for the samples grown in Canada. Since no Canadian varieties were included in this study, it is of less interest to Canadians, and only the more significant data are presented and discussed. Whenever comparisons are made with Canadian and Australian varieties grown in Canada, references are made to tables and figures reproduced earlier.

Grade, Milling and Chemical Data

Table 5 shows that the bushel weights of the Australian varieties ranged from 60 pounds for Gabo to 66 pounds for Celebration. All the wheats milled freely, and gave good yields of flour of low pigment content—particularly Charter and Gular. Protein content was much the highest for Pusa 4 (15.8 per cent), next highest for Charter (14.4 per cent), and between 13.5 and 13.8 per cent for the other varieties. None of the varieties quite equalled Marquis in bushel weight (66.5 lb.), but all were essentially equal to or higher than this variety in protein content (13.7 per cent).

Baking Data

Baking strength paralleled protein content quite closely, and loaf volumes were equal to or higher than that of Marquis. As would be expected from its high protein content, loaf volume for Pusa 4 was highest and above that of both Marquis and Thatcher. Charter and Thatcher were equal in loaf volume. Absorption levels for all the Australian varieties were high and above those of the Canadian varieties. The doughs were very satisfactory and exhibited much the same handling qualities as those of the Australian varieties grown in Canada.

The curves for loaf volume on mixing time for Charter, Yalta, Celebration, and Kendee, were of the same general type as for these varieties grown in Canada (Figure 1), but the levels of the curves at all mixing times were definitely higher, indicating better over-all baking strength. The Australian-grown Charter and Yalta curves were not quite so smooth; they rose more slowly with the shorter mixing times and fell off a little more sharply with the longest mixing time, and had thus a humped appearance.

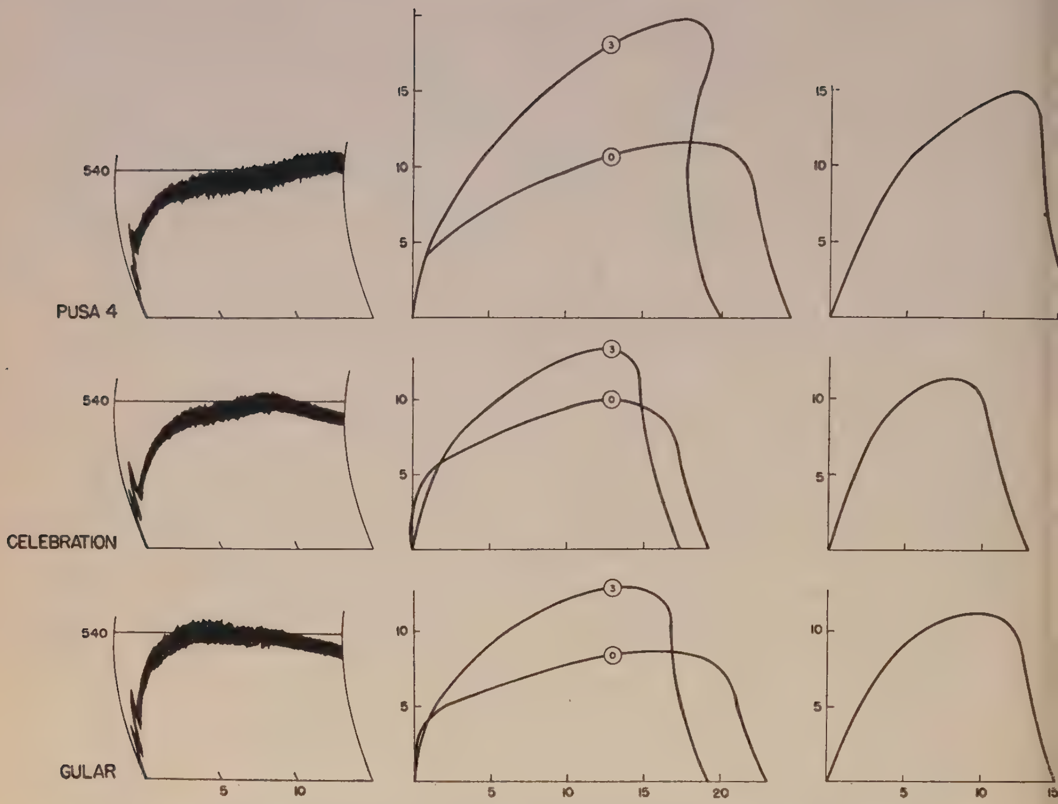

FIGURE 4. Farinograms (*left*), Extensograms for unfermented doughs (*middle*), and Extensograms for fermented doughs (*right*), for Pusa 4, Celebration, and Gular. The numbers on the middle Extensograms indicate milligrams of bromate.

The curve for Gular paralleled at a higher level that of the Canadian-grown sample with the longer mixing times, but loaf volumes were much the same with the shorter mixing times. On the other hand, the curve for Gabo fell off gradually from its beginning, and although loaf volume was higher than that of the Canadian-grown samples with the shorter mixing times, the curves almost coincide with the longer mixing times.

The curve for Pusa 4 differs considerably from that of the other Australian varieties, and is a type not previously encountered with Canadian varieties. Loaf volume was the highest of the series at the beginning, and increased steadily with each mixing time. The curve indicates a very strong flour with great reserve strength. Curves for loaf volume on mixing time for Gular, Gabo, Charter, and Pusa 4 shown in Figure 3 illustrate the range in type among the samples.

Farinograms and Extensograms

The farinograms and extensograms for the varieties grown in Australia were entirely different in type from those of the corresponding varieties grown in Canada, and they indicate physical properties of dough associated

with much stronger samples. Comparison of the data in the lower half of Table 5 with data in Table 4 shows the wide variations in curve measurements between the corresponding varieties, and inspection of the curves themselves shows the differences in type very clearly. Farinograms and extensograms for some of the varieties which illustrate the range in curve type are reproduced in Figure 4.

Without exception, the varieties had longer development times than those of the Canadian-grown samples. The farinograms for Gular, Gabo, and Kendee resemble those of Marquis and Thatcher; that for Yalta was wider and rose steadily without any sign of weakening until the end of the mixing time; and the curves for Pusa 4, Charter, and Celebration, had a second rise after a partial flattening which occurred a little earlier. This unusual type of curve, with an exceptionally long development time, has not been observed in any Canadian variety, and is difficult to interpret without additional experience.

The extensograms, unfermented and fermented doughs, were much taller than those of the Canadian and Australian varieties grown in Canada, and thus indicate much greater resistance to dough stretching. Reaction to bromate was also very great, particularly for Pusa 4, Yalta, and Kendee. The fermented dough curves for these three varieties were also very tall in relation to their length. In general, the extensograms resembled those of the Canadian-grown Cailloux much more than they did those for Marquis and Thatcher, which, although much the same in curve length (extensibility), were not nearly as tall (resistance) and showed less response to bromate.

The farinograms and extensograms reproduced in Figure 4 are for Pusa 4, Celebration, and Gular. The farinograms for Pusa 4 and Celebration show the second rise of the curve referred to; the extensograms for Pusa 4 show the tremendous response to bromate and the high-peaked unfermented dough curve; and the farinogram for Gular shows its resemblance to that of Marquis. The extensograms for Gular, which are about the lowest of the series, when compared with those of Pusa 4, indicate the range in extensogram type for the series.

The results of these various quality tests show that the varieties grown in Australia were, in general, higher in protein content, better in all-round baking strength, and showed more pronounced dough properties, than corresponding varieties grown in Canada. Gular and Gabo are two exceptions to this generalization; for the Australian-grown samples were slightly lower in protein content, though baking strength was just as good, and physical properties of dough were judged to be superior. Pusa 4, the variety grown in Australia but not in Canada, is exceptionally high in protein content and all-round baking behaviour, and in these respects is superior to Marquis and Thatcher. The remaining Australian varieties compare very favourably in protein content and baking strength with Marquis and Thatcher. All the Australian-grown varieties exhibited physical properties of dough that are obviously associated with strong wheats, but they are quite different in these properties from Canadian varieties.

DISCUSSION

Comparative data on the milling and baking qualities of Australian varieties, and of Marquis and Thatcher, should prove useful to Canadian plant breeders in selecting parent materials. Canadian breeding programmes already include crosses made from Charter, Gabo, Gular, and Pusa 4. Data reported in this paper outline the quality characteristics that are being introduced with these Australian varieties. The study may also suggest possibilities for exploiting additional crosses between strong Australian and Canadian varieties.

Some of the Australian varieties, when grown in Western Canada, possess qualities resembling those of Marquis. Gabo seems to be the most attractive variety, for not only do its all-round qualities resemble those of Marquis, but it also yields well, ripens early, and is highly resistant to leaf rust. There is also some evidence to show that it is highly resistant to stem rust. Gular has qualities similar to those of Gabo and Marquis; it ripens midway between Marquis and Thatcher, is much more resistant than Thatcher to leaf rust, but does not yield quite as well as Gabo and is more susceptible to stem rust. Cailloux is another interesting variety which is higher in protein content and all-round baking behaviour than either Gabo or Gular, but it has dough properties that are different from those desired for Canadian varieties. Although Cailloux is an early ripening wheat, it does not yield as well as the other varieties and is more susceptible than Thatcher to leaf rust.

Pusa 4, which originated in India and is now a popular premium wheat in New South Wales, was very high in protein content and baking strength. Unfortunately, data were not obtained in this study on its field performance and quality when grown in Western Canada.

The fact that Australia can produce high-protein wheats of excellent baking quality in parts of New South Wales, and has developed a number of excellent varieties for this area, should cause no surprise. As a parallel case, in eastern provinces and parts of Alberta, Canada produces wheats that are as soft and low in protein as those that make up the bulk of Australian exports.

According to a recent Quarterly Report issued by H. Horace Ward, cargoes of Australian wheat arriving in Great Britain during a three-month period had protein contents ranging between 8.2 per cent (South Australian cargo) and 10.3 per cent (New South Wales cargo). During the same period, protein contents of Canadian cargoes from Atlantic ports averaged 13.3 per cent for No. 1 Northern. Ward states that, except for wheats from New South Wales, the majority of Australian arrivals are more suitable for self-raising and biscuit grists than for bread grists. The protein data presented in the report represent the normal spread in protein content (3 to 4 per cent) that has existed for years between Australian and Canadian shipments. There is no reason to believe that this situation will change in the near future.

It must also be borne in mind when comparing the data reported in this paper for the Australian-grown varieties with those for Marquis and Thatcher, that the Australian-grown varieties were grown in one location only, whereas the Canadian varieties were composite samples representing

four widely separated points at which protein content varied considerably. Had the high-protein samples of Canadian varieties from Swift Current only been used for comparison with the varieties grown in Australia, the Canadian varieties would have been higher in protein content and baking strength. On the other hand, the data obtained in this study show that Australia produces some varieties that are excellent in quality and fully equal to the standard expected of good Canadian varieties. These wheats are not at present grown in large quantities and are held for domestic use.

SUMMARY

Eight varieties of Australian bread wheats were grown with Thatcher and Marquis at four stations in Canada. Samples of six of the varieties, and of a seventh not grown in Canada, were obtained from a single station in New South Wales.

Gabo and Gular, which are resistant to leaf rust, and have generally satisfactory milling and baking qualities, may prove useful to Canadian plant breeders. Cailloux and Pusa 4 are interesting because of their baking strength, but have dough properties different from those of Canadian varieties.

The study shows that a number of Australian varieties are fully equal to Marquis in baking strength. Moreover, Australia can produce some wheat as high in protein content as Canadian export wheat, just as Canada can produce some wheat as low in protein content as Australian export wheat.

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A TRACTOR MOUNTED METER ATTACHMENT FOR SIDE BAND APPLICATION OF FERTILIZER TO TOBACCO PLOTS

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Manual methods of applying fertilizer for burley tobacco plots were found unsatisfactory and available commercial equipment was not sufficiently flexible or accurate for experimental requirements. A machine was required that would apply, accurately, the fertilizer to the plots in concentrated bands at a desired position on each side of the tobacco row. The unit had to be capable of handling rates up to 1,000 pounds per acre for 1/40th acre plots. A positive control of the fertilizer was necessary to ensure accuracy and to eliminate loss of fertilizer at the ends of the plot rows. Other features, such as simplicity of mounting and adjustment, as well as adequate manoeuverability, were also desirable. In an attempt to meet these requirements the following unit was assembled.

DESCRIPTION OF UNIT

The unit consists of two single row, belt-type, walking-fertilizer distributors (1) mounted on a tractor equipped with a one-row cultivator. Two brackets, made of 2 in. angle iron, are fixed on the right side of the tractor to form a support 38 in. above the ground level. The front bracket is attached to the cultivator frame and extends 29 in. from the tractor, while the rear bracket is attached to the centre mounting pad of the tractor and projects 32 in. These brackets form the base on which the two fertilizer meter devices are fitted.

The drive mechanism consists of the mounting bracket, drive shaft and clutch from a commercial fertilizer distributor attachment for the cultivator. To this is connected, by a chain drive, a second shaft, to drive the individual roller chains operating the two meter devices. By using the commercial distributor drive and clutch, provision is made to disengage the units when the cultivator is lifted. It also allows the original device to be installed with a minimum of effort when the machine is required for general field work.

The meter device consists of a tray $4\frac{1}{2}$ in. deep, 5 in. wide and 32 in. long, mounted on an endless canvas belt. When the tray is moved towards the rear, the fertilizer is delivered to the distribution pipe from the rear of the endless belt. To ensure accurate metering, a circular brush is used to sweep a uniform amount of fertilizer from the belt. Flexible tubes deliver the fertilizer to openers that place the material accurately in concentrated bands.

A rack and pinion actuate the tray and move it 21 in. towards the rear, when the unit is set for maximum travel. A stop is provided to allow the length of travel to be easily adjusted. With a 14-tooth drive sprocket,

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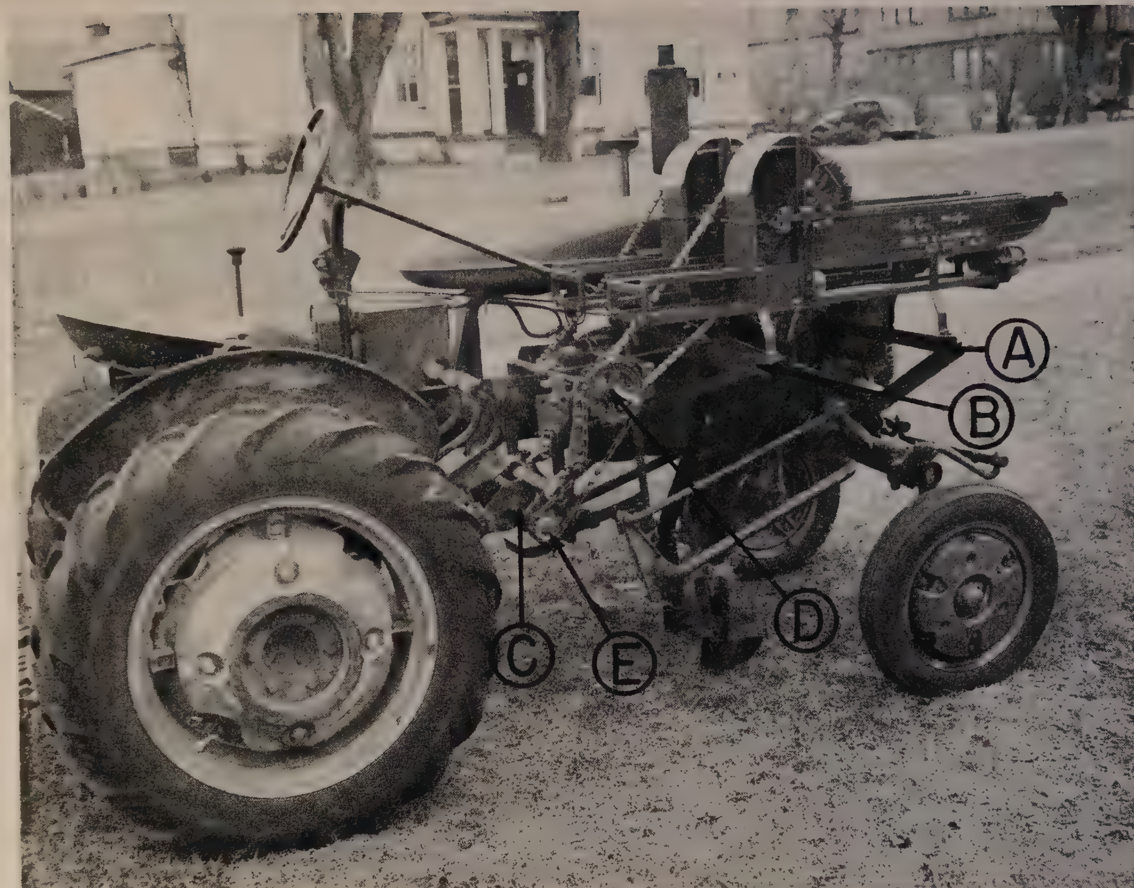

FIGURE 1. Side view of unit showing:

(A) Front bracket
(B) Rear bracket
(C) Drive shaft of fertilizer distributor
(D) Second drive shaft, chain driven by clutch operated drive shaft
(E) Interchangeable sprocket on (C)

FIGURE 3. Fertilizer levelled in trays ready for distribution.

FIGURE 4. Openers placing the fertilizer in the soil.

FIGURE 2. Tractor with fertilizer attachment in operation.

one tooth on the rack is equal to 3 feet of ground travel. The distance travelled is easily calculated by counting the teeth and setting the stop on the rack. A minimum length of row of 50 feet and a maximum of 340 feet are possible by using a 14-tooth sprocket. By substituting an 8-tooth drive sprocket, 600 feet of row may be treated. Other variations in the row length are possible by the use of suitable sprockets (Figure 1).

ATTACHMENT AND OPERATION OF THE FERTILIZER UNIT

Once the original assembly had been completed the device was found convenient and simple to attach and operate. In approximately one hour two men attached the complete fertilizer unit including the front and rear cultivator gangs (Figure 2). When interchanging was necessary between the meter unit and the commercial hopper, the change-over took about half an hour. The mounting brackets for both these parts remained in place for more than a month without restricting utility of the tractor for other purposes.

In preparing to use the machine, the fertilizer is measured in advance for each plot and the total amount of fertilizer necessary for each treatment is divided equally into two bags. These are tagged and distributed to their respective plots in the field. The openers on the machine are adjusted to place the fertilizer at the required depth and distance from the row. The stop on each of the racks is adjusted to allow the trays to move the correct distance while the tractor moves over the four rows of the plot. At each plot the previously prepared fertilizer is dumped into the trays and carefully levelled. The tractor enters the plot and discharges the fertilizer into the soil beside the rows as required. As each plot is finished the rack is tripped, the tray is returned to the forward position and reset for the next plot. The complete operation requires not more than five minutes per plot (Figure 3).

Very little difficulty was experienced in the operation of the equipment, providing the fertilizer was reasonably dry and free-flowing. However, as a safeguard against error caused by clogging in the tubes or misjudgment in operation, one guard row was treated first, followed by the two middle yield rows, and finally the other guard row. The openers placed the fertilizer in concentrated bands as required with a minimum disturbance of the soil (Figure 4). The regulation of fertilizer flow was uniform when the fertilizer was properly levelled in the trays. Similar tests with other row crops and in plots of different sizes using a wide range of rates of application proved the flexibility of the equipment.

SUMMARY

A special machine was required for side band application of fertilizer in burley tobacco experimental plots since neither manual methods nor available commercial fertilizer equipment was suitable for this purpose. The equipment was required to incorporate the features of adequate manoeuverability combined with accurate and uniform placement of fertilizer at rates up to 1,000 pounds per acre. A belt-type, walking-fertilizer distributor was modified to operate in conjunction with the drive mechanism of a commercial fertilizer attachment for a single-row tractor cultivator. Intensive tests under actual working conditions have demonstrated the flexibility and utility of this machine in several fertilizer placement experiments.

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